Marine Fisheries
REVIEW
Vol. 66, No. 3
2004
United States Department of Commerce

Sablefish

Marine Fisheries REVIEW

W. L. Hobart, Editor
J. A. Strader, Managing Editor

On the cover: A lone sablefish, *Anoplopoma fimbria*, swims near soft bottom substrate in the cold waters off of Alaska. Photo by Pat Malecha, NMFS.

Articles *66(3), 2004*

U.S. DEPARTMENT OF COMMERCE
Carlos M. Gutierrez, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Vice Admiral
Conrad C. Lautenbacher, Jr.,
U.S. Navy (Ret.), Under Secretary for Oceans and Atmosphere

National Marine Fisheries Service
William T. Hogarth
Assistant Administrator for Fisheries

The *Marine Fisheries Review* (ISSN 0090-1830) is published quarterly by the Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., BIN C15700, Seattle, WA 98115. Annual subscriptions are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. The annual subscription price is $21.00 domestic, $29.40 foreign. Single copies are $12.00 domestic, $16.80 foreign. For new subscriptions write: New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

POSTMASTER: Send address changes for subscriptions for this journal to: *Marine Fisheries Review*, c/o Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. This issue, volume 66 number 3, was printed and distributed in January 2006.

This publication is available online at http://spo.nwr.noaa.gov/mcontent.htm

Sablefish, *Anoplopoma fimbria*, Populations on Gulf of Alaska Seamounts

NANCY E. MALONEY

Introduction

The Gulf of Alaska seamounts are a group of undersea mountains of volcanic origin rising from the ocean floor at depths of 3,200–4,000 m to within 400–800 m of the surface (Fig.1). They are located in the eastern and central Gulf of Alaska at distances of 270–465 km offshore. Half of the major seamounts in this group fall within the U.S. Exclusive Economic Zone and half are outside; all are separated from the continental slope by waters from 2,900 to about 5,000 m in depth.

NOAA's National Marine Fisheries Service (NMFS) first conducted exploratory fishing on nine Gulf of Alaska (GOA) seamounts in June and July 1979 (Hughes, 1981). Using trawls and traps, they found that sablefish, *Anoplopoma fimbria*, were the dominant finfish on each of the seamounts and that trap catch rates of sablefish were higher than those from NMFS survey sites off southeastern Alaska. There were more than twice as many males as females, and nearly all sablefish were ripe, spawning, or recently spent. However, only older and larger fish were caught on the seamounts, suggesting that the seamount populations are maintained by the migration of mature fish from the continental slope rather than by local recruitment.

Tagged sablefish released in the Bering Sea, Aleutian Islands (BSAI) region, and the western and central GOA have been recovered on GOA seamounts, verifying the occurrence of slope to seamount migration (Shaw and Parks, 1997). Of 99 tagged sablefish released on 5 GOA seamounts in 1979, 5 have been recovered on the seamount where they were tagged, and none have been recovered elsewhere.

NMFS revisited seven of the seamounts sampled in 1979 and one (Murray Seamount) that was not sampled in 1979. Sablefish were tagged and released on the seamounts during 1999–2002 to determine the extent, if any, of emigration from the seamounts back to the continental slope and movement between seamounts. A second objective was to gather biological information from the seamount sablefish populations.

Materials and Methods

Seamount sampling was conducted aboard chartered commercial fishing vessels during NMFS longline surveys in 1999–2002. These longline surveys, conducted annually, sample stations along the continental slope of the Bering Sea and Aleutian Islands (alternate years) and the GOA (every year) to determine the relative abundance and size composition of commercially important species. During the survey each year, several thousand sablefish are tagged and released to provide information on growth and movement rates. Three seamounts per year were sampled during the first week of July. Giacomini, Surveyor, and Pratt Seamounts were sampled in 1999. In 2000, Surveyor and Pratt were revisited and Welker Seamount was sampled for the first time. Surveyor was sampled for the third time in 2001, Welker for the second time, and Dickens Seamount for the first time. Patton, Murray, and Durgin Seamounts were sampled in 2002. A total of 12 samples were taken at 8 seamounts from 1999 to 2002 (Table 1).

Nancy E. Maloney is with the Auke Bay Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 11305 Glacier Highway, Juneau, AK 99801 (e-mail: nancy.maloney@noaa.gov).

ABSTRACT—Sablefish, Anoplopoma fimbria, *were tagged and released on Gulf of Alaska seamounts during 1999–2002 to determine the extent, if any, of emigration from the seamounts back to the continental slope and of movement between seamounts. Seventeen sablefish from Gulf of Alaska seamounts have been recovered on the continental slope since tagging began, verifying that seamount to slope migration occurs. Forty-two sablefish were recovered on the same seamounts where they were tagged, and none have been recaptured on seamounts other than the ones where they were released.*

Sablefish populations on Gulf of Alaska seamounts are made up of individuals mostly older than 5 years and are male-dominant, with sex ratios varying from 4:1 up to 10:1 males to females. Males are smaller than females, but the average age of males is greater than that of females, and males have a greater range of age (4–64 yr) than females (4–48 yr). Otoliths of seamount fish frequently have an area of highly compressed annuli, known as the transition zone, where growth has suddenly and greatly slowed or even stopped. Because transition zones can be present in both younger and older seamount fish and are rare in slope fish, formation of otolith transition zones may be related to travel to the seamounts.

The route sablefish use to reach the seamounts is so far unknown. One possibility is that fish enter the eastward-flowing North Pacific Current off the Aleutian Islands or western Gulf of Alaska and travel more or less passively on the current until encountering a seamount. The route from seamount back to slope would likely be the northward-flowing Alaska Current. These routes are discussed in light of tag recovery locations of slope- and seamount-tagged fish.

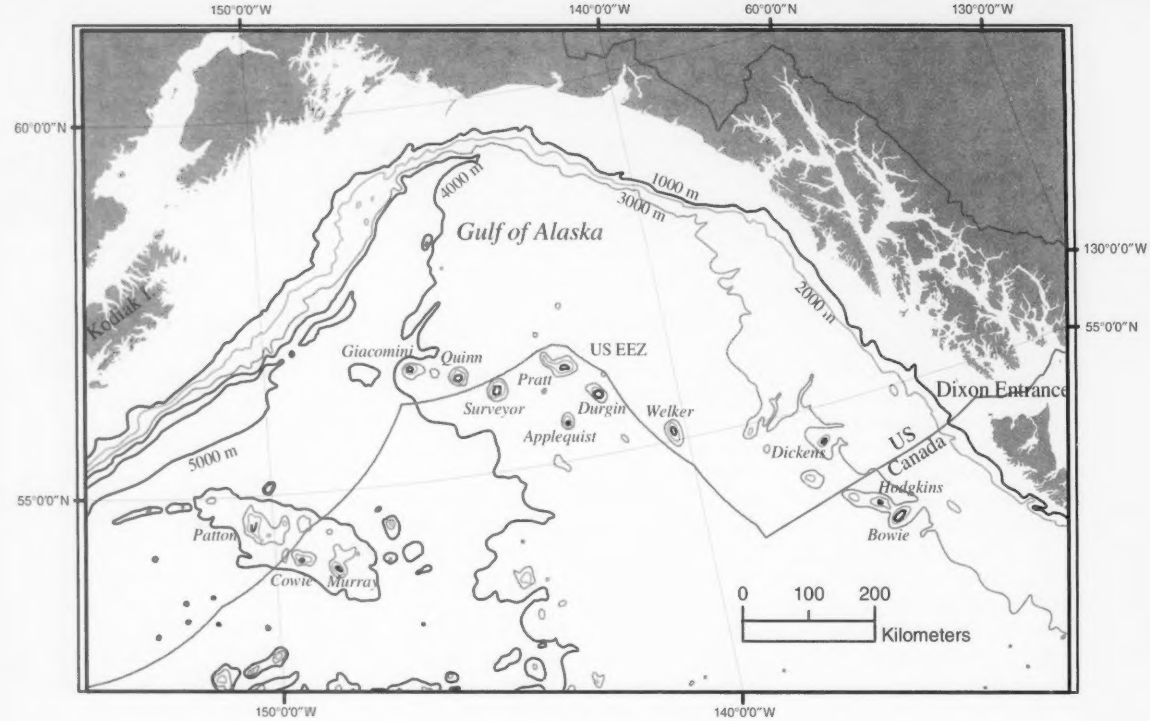


Figure 1.—Gulf of Alaska seamounts.

Standard survey longline gear and techniques (Rutecki[1]) were used on the seamounts. At each seamount, 2 sets of 80 skates each with a total of 7,200 hooks were set and retrieved. Two exceptions to this were Giacomini Seamount in 1999 and Dickens Seamount in 2001, where only 120 skates were set. Some skates were also lost on Dickens Seamount due to entanglement in rough substrate. Catch data were recorded on a hand-held electronic data logger during gear retrieval and subsequently downloaded to a computer. Length frequency and sex data were collected with a bar-code-based measuring board and a bar-code reader/data storage device (Sigler, 1994). Usually, all sablefish that were not either tagged or sampled for otoliths were measured and sexed. Sablefish lengths were combined by year to ensure adequate sample sizes.

Table 1.—Gulf of Alaska seamounts sampled by NMFS in 1979 and 1999–2002.

			Year sampled (X)				
Seamount	Lat.	Long.	1979	1999	2000	2001	2002
Applequist	55°28.5'N	142°46.4'W	X				
Dickens	54°31.3'N	136°56.0'W	X			X	
Durgin	55°50.0'N	141°51.5'W	X				X
Giacomini	56°27.5'N	146°24.0'W	X	X			
Murray	53°57.0'N	148°31.0'W					X
Patton	54°34.4'N	150°29.5'W	X				X
Pratt	56°14.4'N	142°32.0'W	X	X	X		
Quinn	56°18.3'N	145°13.1'W	X				
Surveyor	56°03.1'N	144°19.3'W	X	X	X	X	
Welker	55°06.7'N	140°20.6'W	X		X	X	

Starting with the fifth skate of each set, the first three sablefish of every tenth skate were set aside for age and condition sampling. These fish were weighed and measured, their stage of sexual maturity noted, and their otoliths collected and stored in a 50% ethyl alcohol solution for later ageing in the laboratory. Otoliths were read by experienced readers of the Age and Growth Program at the NMFS Alaska Fisheries Science Center (AFSC) in Seattle, Wash., using the ageing methods of Beamish and Chilton (1982). A total of 440 sablefish were aged. The first 150 sablefish of each set, except for fish set aside for otolith extraction or fish that were damaged during retrieval, were tagged with anchor tags, measured for length, and released. Release and recovery data discussed here were ob-

[1]Rutecki, T. 2004. Longline survey of the Gulf of Alaska and Eastern Bering Sea, May 28–September 1, 2003. Cruise Report OP-01-03. U.S. Dep. Commer., NOAA, NMFS, Auke Bay Lab., 11305 Glacier Hwy., Juneau, AK 99801.

Table 2.—Numbers of individuals of fish and invertebrate species caught on Gulf of Alaska seamounts during sablefish longline surveys, 1999–2002.

	Common name	Total catch	Common name	Total catch	Common name	Total catch
1999	**Giacomini**		**Surveyor**		**Pratt**	
	Giant grenadier	1,019	Giant grenadier	1,448	Giant grenadier	985
	Sablefish	933	Sablefish	785	Sablefish	689
	Pacific grenadier	229	Rougheye, shortraker	124	Longspine thornyhead	72
	Pacific flatnose	9	Pacific flatnose	39	Pacific grenadier	15
	Coral	9	Longspine thornyhead	28	Tanner crab	10
	Longspine thornyhead	7	Shortspine thornyhead	16	Pacific flatnose	4
	Sponge	4	Tanner crab	7	Sponge	3
			Pacific grenadier	6	Starfish	2
			Coral	4	Shortspine thornyhead	2
			Starfish	2	Scarlet king crab	4
			Salmon	2	Coral	1
2000	**Surveyor**		**Pratt**		**Welker**	
	Giant grenadier	1,486	Giant grenadier	1,128	Sablefish	2,158
	Sablefish	666	Sablefish	684	Giant grenadier	330
	Shortspine thornyhead	33	Longspine thornyhead	41	Pacific flatnose	13
	Longspine thornyhead	27	Pacific grenadier	11	Pacific grenadier	10
	Pacific flatnose	13	Starfish	7	Longspine thornyhead	6
	Starfish	5	Shortspine thornyhead	5	Tanner crab	5
	Coral	5	Tanner crab	4	Sea anemone	5
	Brittle starfish	4	Pacific flatnose	4	Starfish	1
	Pacific grenadier	3	Scarlet king crab	6	Sponge	1
	Scarlet king crab	4	Spiny dogfish	2	Sea cucumber	1
	Rougheye, shortraker rockfish	2	Sea anemone	1		
	Tanner crab	1				
2001	**Surveyor**		**Welker**		**Dickens**	
	Giant grenadier	692	Sablefish	1,325	Sablefish	1,395
	Sablefish	326	Giant grenadier	488	Rougheye, shortraker rockfish	667
	Pacific flatnose	178	Pacific grenadier	168	Giant grenadier	52
	Longspine thornyhead	70	Pacific flatnose	58	Coral	10
	Shortspine thornyhead	66	Longspine thornyhead	8	Aurora rockfish	6
	Pacific grenadier	47	Tanner crab	8	Shortspine thornyhead	3
	Starfish	10	Coral	4	Scarlet king crab	3
	Coral	4	Sponge	2	Pacific sleeper shark	2
	Tanner crab	1			Starfish	1
	Sea anemone	1			Pacific flatnose	1
					Golden king crab	1
					Blackfin sculpin	1
					Pomfret	1
2002	**Patton**		**Murray**		**Durgin**	
	Giant grenadier	1,695	Giant grenadier	2,941	Giant grenadier	332
	Sablefish	957	Pacific grenadier	827	Sablefish	255
	Shortspine thornyhead	56	Sablefish	83	Longspine thornyhead	28
	Brittle starfish	54	Pacific flatnose	21	Pacific flatnose	22
	Rougheye, shortraker rockfish	41	Coral	14	Tanner crab	7
	Crinoid	29	Scarlet king crab	2	Scarlet king crab	6
	Pacific grenadier	4	Coho salmon	2	Pacific grenadier	3
	Longspine thornyhead	4	Tanner crab	1	Starfish	2
	Scarlet king crab	4	Sea anemone	1	Sea anemone	1
	Coral	4				
	Pacific flatnose	3				
	Aurora rockfish	2				
	Starfish	1				
	Golden king crab	1				
	Sponge	1				

tained from the NMFS Sablefish Tag Database, described in detail by Fujioka et al. (1988).

Results

Catch

Sablefish were the most numerous finfish on 3 of the 12 seamount visits between 1999 and 2002 (Welker Seamount in 2000 and 2001, and Dickens Seamount in 2001) (Table 2). Giant grenadier, *Albatrossia pectoralis*, dominated catches on the other nine visits. Pacific grenadier, *Coryphaenoides acrolepis*, were present in substantial numbers on several seamounts and replaced sablefish as the second-most common species on Murray Seamount in 2002. A list of scientific and common names of fish and crustaceans caught on the seamounts during 1999–2002 may be found in Table 3. Catch per unit of effort (CPUE), calculated as number of sablefish per 100 hooks, is shown for each seamount and year in Table 4.

CPUE varied greatly between seamounts, ranging from highs of 30.0 and 29.8 on Welker Seamount (2000) and Dickens Seamount (2001) to lows of 1.2 and 3.5 on Murray and Durgin Seamounts in 2002. CPUE on Surveyor Seamount, the only seamount to be sampled

in three consecutive years, declined from 10.9 in 1999 to 4.5 in 2001.

Hughes (1981) and Alton (1986) reported that sablefish was the dominant demersal finfish species on each of the nine GOA seamounts sampled in 1979. Because the 1999–2002 fishing was all by longline and the 1979 fishing was with trap, pot, or trawl, no direct comparisons can be made.

Biological Characteristics

Male sablefish were more abundant (Fig. 2) and smaller than females in all years, and the size ranges for males and females (Table 5) were similar to those found by Hughes (1981), although he found no males smaller than 52 cm and no females smaller than 58 cm. In 1999–2002 sampling, 51 cm males were caught on three seamounts, and several females smaller than 58 cm were caught, including one at 49 cm. The average length of males by year and seamount was similar, ranging between 61.7 and 63.7 cm (Table 5). The average length of females by year and seamount had a slightly wider range of 67.4–75.1 cm.

Most of the stations sampled during 1999–2002 had at least a 4:1 preponderance of males, and several stations approached or exceeded a 10:1 ratio (Table 6). Hughes (1981) found that male sablefish outnumbered females by about 2:1 on the seamounts he sampled in 1979.

Otoliths from seamount sablefish were far more difficult to age than otoliths of slope sablefish collected during the longline survey, due to the greater age and extremely compressed pattern of annuli of seamount fish. Compressed annuli indicate that growth is very slow; it even may stop with no increase in fish length with age.[2] This is illustrated by the combined plot of age vs. length for all the seamount samples (Fig.3).

Another characteristic of many otoliths from seamount fish was that growth patterns were typical for sablefish otoliths of young fish, but suddenly transitioned to the compressed pattern. A similar pattern is seen occasionally in fish sampled from the longline survey[2], but the pattern is common in otoliths from seamount sablefish. Referred to as the "transition age," the beginning of the compressed zone may indicate the age at which fish traveled to the seamounts. Transition ages of 152 sablefish were read. Most occurred between 5 and 15 years, regardless of age of the fish. The four oldest transition ages were those of three females and a male between 20 and 24 years old. The youngest transition ages were of six males at 3–4 years. The average transition age for males was 8.7 years (S.E. mean = 0.3) and the average for females was 11.7 years (S.E. mean = 1.8). The greatest number of ages at transition for males were between 6 and 8 years; the greatest number of ages at transition for females were between 8 and 11 years (Fig. 4).

The average age and the range of ages of males are greater than of females at all seamounts (Table 7). Except for Patton and Murray Seamounts in 2002, most of the females were younger than 18 years. Except for Dickens Seamount in 2001, where the oldest male was 29 years, males up to 40 years old were present, and there were some fish more than 60 years old (Fig. 5). Males from 55 year classes between 1936 and 1997 were present on the seamounts sampled during 1999–2002, while females from only 33 year classes between 1952 and 1997 were found (Fig. 6).

All of the sampling during 1999–2002 was in the first week of July. Most of the fish during these years were ripe, spawning, or recently spent, but there were some fish in the resting stage (Table 8). There was some difference in stage between the sexes: the highest per-

Table 3.—Scientific and common names of fish and crustaceans caught on Gulf of Alaska seamounts during sablefish longline surveys, 1999–2002.

Scientific name	Common name
Fish	
Albatrossia pectoralis	Giant grenadier
Anoplopoma fimbria	Sablefish
Antimora microlepis	Pacific flatnose
Bramidae	Unident. pomfret
Coryphaenoides acrolepis	Pacific grenadier
Malacocottus kincaidi	Blackfin sculpin
Oncorhynchus kisutch	Coho salmon
Oncorhynchus sp.	Unident. salmon
Sebastes aleutianus	Rougheye rockfish
Sebastes aurora	Aurora rockfish
Sebastes borealis	Shortraker rockfish
Sebastolobus alascanus	Shortspine thornyhead
Sebastolobus altivelis	Longspine thornyhead
Somniosus pacificus	Pacific sleeper shark
Squalus acanthias	Spiny dogfish
Crustaceans	
Chionoecetes tanneri	Grooved tanner crab
Lithodes aequispina	Golden king crab
Lithodes couesi	Scarlet king crab

Table 4.—Catch per unit effort (CPUE) of sablefish, calculated as number/100 hooks, caught on Gulf of Alaska seamounts during sablefish longline surveys, 1999–2002.

Year	Seamount	Sablefish	Hooks	CPUE
1999	Giacomini	933	5,400	17.3
	Surveyor	785	7,200	10.9
	Pratt	689	7,200	9.6
2000	Surveyor	666	7,200	9.3
	Pratt	684	7,200	9.5
	Welker	2,158	7,200	30.0
2001	Surveyor	326	7,200	4.5
	Welker	1,325	7,200	18.4
	Dickens	1,395	4,680	29.8
2002	Patton	957	7,200	13.3
	Murray	83	7,200	1.2
	Durgin	255	7,200	3.5

Table 5.—Mean length, standard error (SE), range of lengths, and sample size (N) of male and female sablefish sampled on Gulf of Alaska seamounts in 1999–2002.

		Males				Females			
Year	Seamount	Mean length	SE	Range	N	Mean length	SE	Range	N
1999	Giacomini	61.7	0.1	55–74	469	72.5	1.0	55–88	47
	Surveyor	63.1	0.1	54–79	445	73.2	0.6	61–87	77
	Pratt	62.3	0.2	51–76	365	71.2	0.5	61–87	77
2000	Surveyor	63.6	0.2	55–77	278	74.1	0.8	58–92	76
	Pratt	62.8	0.2	54–74	304	72.4	0.7	59–85	61
	Welker	62.0	0.1	51–77	1,429	70.0	0.3	57–82	241
2001	Surveyor	61.9	0.6	51–67	38	67.4	4.0	49–85	5
	Welker	62.6	0.1	52–75	737	70.9	0.4	56–84	181
	Dickens	62.5	0.1	53–76	870	72.6	0.6	56–87	107
2002	Patton	63.7	0.2	54–79	488	74.1	0.9	60–93	100
	Murray	62.2	0.6	57–68	22	75.1	2.5	67–91	9
	Durgin	62.0	0.7	56–68	24	72.0	2.1	69–76	3

[2]Anderl, D. Age and Growth Program, NMFS Alaska Fisheries Science Center, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115. Personal commun., November 2000.

Table 6.—Percentages of male and female sablefish in samples taken on Gulf of Alaska seamounts, 1999–2002.

Year	Seamount	Sex ratio	
		% Males	% Females
1999	Giacomini	90.9	9.1
	Surveyor	85.2	14.8
	Pratt	82.6	17.4
2000	Surveyor	78.5	21.5
	Pratt	83.1	16.7
	Welker	85.6	14.4
2001	Surveyor	81.4	18.6
	Welker	80.3	19.7
	Dickens	89.1	11.0
2002	Patton	83.0	17.0
	Murray	71.0	29.0
	Durgin	88.9	11.1

centage of males were in recently spent condition, while most females were still spawning. Hughes (1981) also found that nearly all sablefish were ripe, spawning, or recently spent during his sampling in June and July of 1979.

Tag Recoveries

A total of 3,327 sablefish were tagged and released on GOA seamounts during 1999–2002. Forty-two of these fish were recovered on the same seamount where they were tagged within 1, 2, or 3 years. No tagged fish has been recaptured on a seamount other than the one it was released on.

Seventeen of the tagged sablefish were recovered on the continental slope, verifying that seamount to slope migration occurs. Five of the slope recoveries were from Welker Seamount, four from Giacomini Seamount, three each from Surveyor and Dickens Seamounts, and one each from Pratt and Patton Seamounts (Fig. 7). Catch locations were unavailable for one each of the recoveries from Giacomini and Welker Seamounts. The remaining three recoveries from Giacomini were caught within 105 mi of each other and had the shortest distances from release to recovery location, averaging only 146.5 mi.

Although more than 150 sablefish tagged in Alaska coastal and continental slope waters have been recovered on seamounts off British Columbia and the Washington coast, only seven recoveries of fish released in Alaska waters have been made on GOA seamounts. This difference is due in part to the much

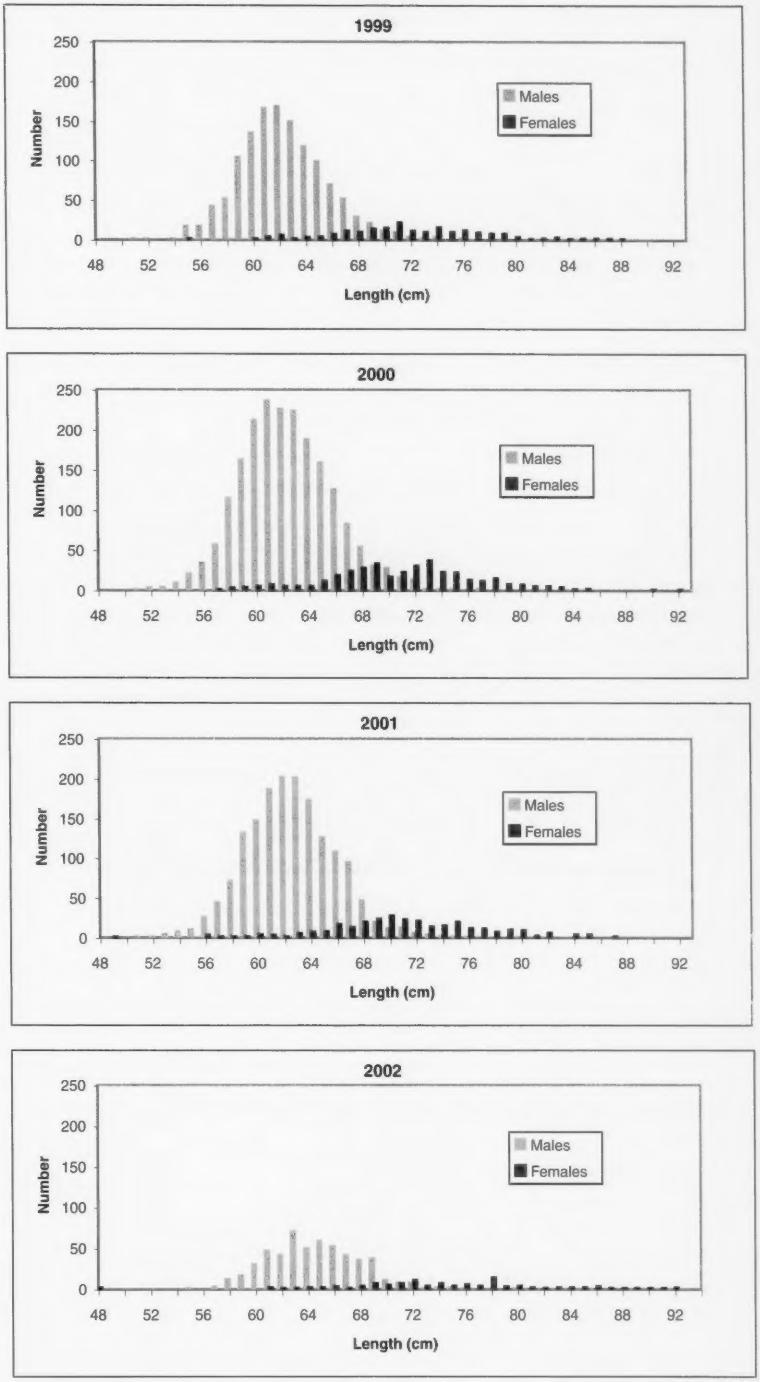


Figure 2.—Sablefish length frequency by sex and year for seamount samples taken during 1999–2002.

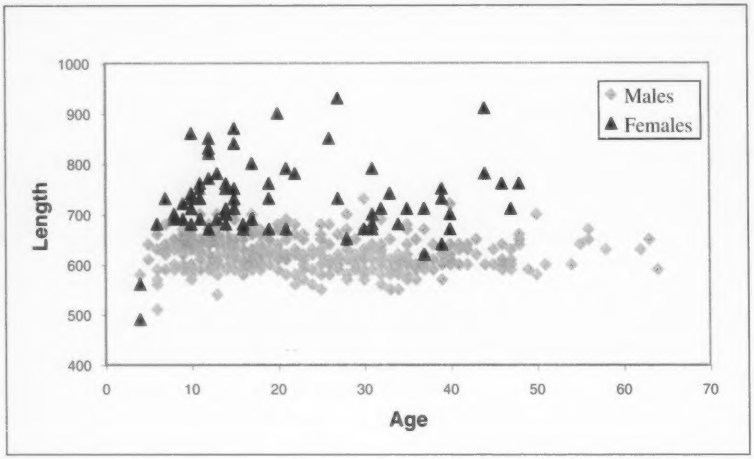


Figure 3.—Sablefish age vs. length for 440 seamount age samples taken during 1999–2002.

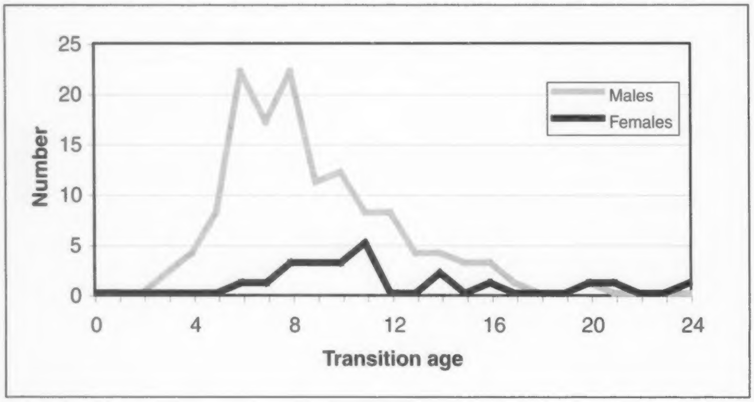


Figure 4.—Transition ages of 152 sablefish caught on Gulf of Alaska seamounts between 1999 and 2002.

Table 7.—Mean age of male and female sablefish on Gulf of Alaska seamounts, 1999–2002.

		Mean age			
Year	Seamount	Males	SE	Females	SE
1999	Giacomini	30.0	2.9	23.8	8.2
	Surveyor	24.0	2.6	14.8	1.3
	Pratt	22.5	2.1	16.7	3.4
2000	Surveyor	23.1	2.4	22.4	3.4
	Pratt	23.6	2.4	12.9	0.8
	Welker	21.1	1.7	11.3	1.7
2001	Surveyor	19.2	1.9	14.6	4.0
	Welker	16.9	1.6	12.8	2.0
	Dickens	13.7	1.1	9.8	0.6
2002	Patton	31.1	2.1	29.0	2.7
	Murray	31.3	2.3	32.3	4.0
	Durgin	29.3	3.2	12.7	2.2

greater fishing effort expended on British Columbia and Washington seamounts, especially Bowie Seamount. The seven recoveries made on GOA seamounts include two each from the Bering Sea, Aleutian Islands, and central GOA and one from the western GOA (Fig. 8). No fish tagged in the eastern GOA or east of Kodiak Island in the central GOA have been recovered on GOA seamounts. In contrast, about half of the 130 sablefish tagged in Alaska waters and recovered on Bowie Seamount were released in the eastern GOA, with the remainder coming from the Aleutian Islands (8.0%), the Bering Sea (11.5%), the western GOA (10.0%), and the central GOA (22.3%).

Discussion

Several biological characteristics of sablefish found on GOA seamounts are notably different from those of sablefish on the continental slope. The sablefish population on the slope is maintained by the movement of younger, immature fish from shallow inshore waters to deeper offshore waters as they mature (Sasaki, 1983). In contrast, only larger, mature sablefish are found on the seamounts, indicating that these populations are maintained by recruitment of adult fish from the slope rather than local reproduction. Of 440 seamount fish aged, only 7 were younger than 6 years old and none were younger than 4 years old.

Alton (1986) thought that the lack of young fish on the seamounts, together with the fact that males mature at a younger age than females and younger ages are usually more numerous than older ages, helped explain a preponderance of males on the seamounts. Hughes (1981) found twice as many males as females in his combined sample from eight seamounts. Murie et al. (1996) also found sex ratios biased toward males in their study of the Canadian trap fishery for sablefish on northeastern Pacific seamounts. Sixty-four percent of the recoveries from Bowie Seamount in the NMFS sablefish tag database are males. Results from the 1999–2002 samples were even more uneven, with ratios as high as 10:1 and 8:1 males to females on several seamounts, and 4:1 or 5:1 on most of the remaining seamounts

(Table 6). The sex ratio of sablefish taken by longline on the Alaska continental shelf and slope is reversed, with an estimated 1.5 female sablefish to every male.[3] Mason et al. (1983) found the same ratio in trawl studies along the west coast of Canada. In Alaska, this ratio is established in the population by age 2, so it is unlikely that it is a result of more males migrating to the seamounts.

As noted earlier, otoliths of many seamount fish typically start off with normal growth but suddenly transition into the compressed growth pattern. The fact that 55% of seamount otoliths examined in 1999 and 73% examined in 2002 had a well-defined transition zone, while transition zones are seen only occasionally in slope fish, suggests that transition age is related to presence on seamounts. The occurrence of transition zones at age 3 or 4 as well as the more common transition ages of 5–15 indicates that the formation of the transition zone may well take place during or just subsequent to migration to the seamounts.

If this is so, then the difference in the average transition age between males (8.7) and females (11.7) may help explain the disproportionate numbers of males and their higher average age and greater age range than females on the seamounts. Most of the males on seamounts leave the slope at age 6–8, within 1 or 2 years after reaching sexual maturity. Females of the same year class remain on the slope on average 3 years longer before travelling to the seamounts. During this time they are vulnerable to fishing and their numbers are consequently lowered, so that fewer females than males from any given year class travel to the seamounts. Assuming equal survival rates for males and females on the seamounts, higher average age and greater age range of males come about as, over time, the smaller numbers of females in each year class die off before the larger number of males.

Most sablefish undertake a migration from eastern areas of the Gulf of Alaska to western areas, including the Aleutian

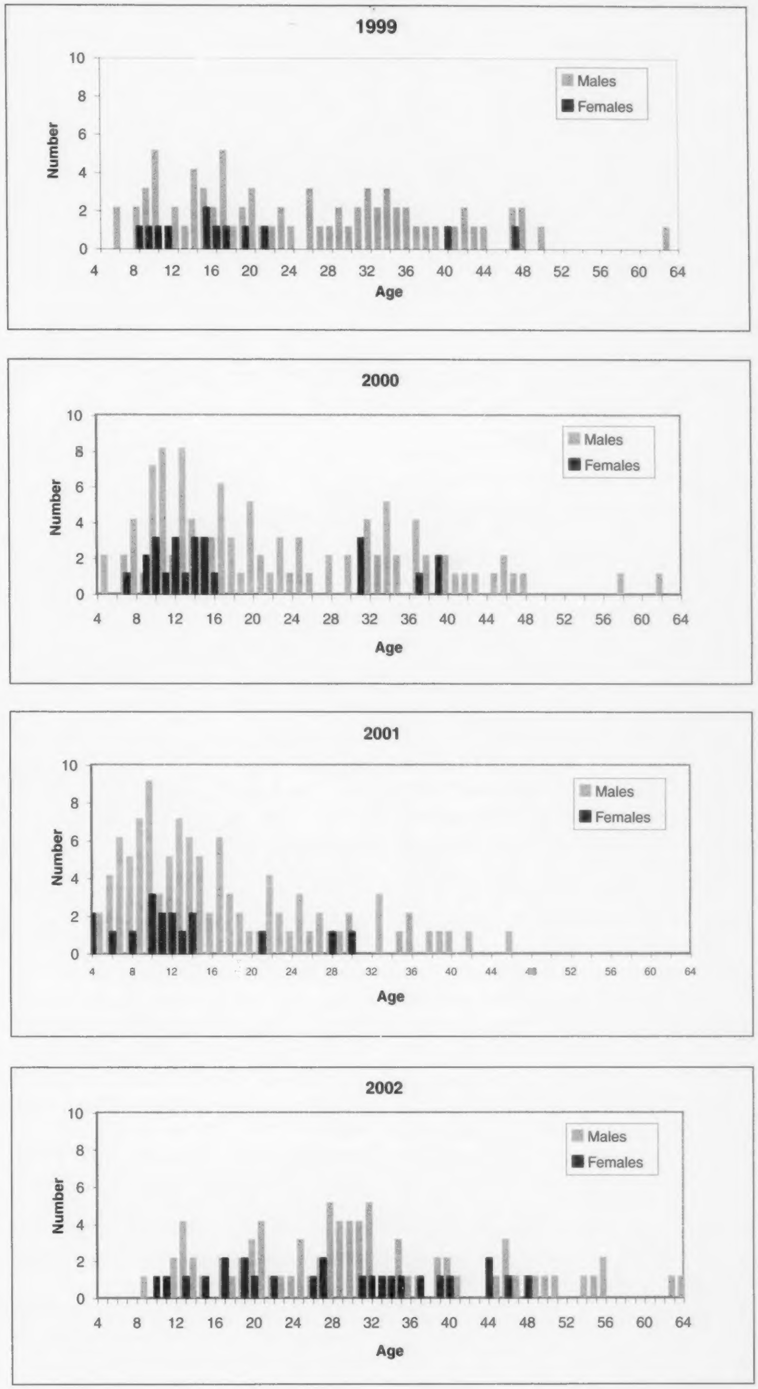


Figure 5.—Sablefish age by sex and year for seamount samples taken in 1999–2002.

[3]Sigler, M. Groundfish Program, NMFS, Alaska Fisheries Science Center, NOAA, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801. Personal commun., March 2004.

Table 8.—Stages of maturity (%) of male and female sablefish sampled on Gulf of Alaska seamounts, 1999–2002.

		Stage of maturity (%)							
		Males				Females			
Year	Seamount	Resting	Ripe	Spawning	Spent	Resting	Ripe	Spawning	Spent
1999	Giacomini	26.8	2.4	2.4	68.3		20.0	80.0	
	Surveyor	2.4		11.9	85.7			75.0	25.0
	Pratt			7.3	92.7			100.0	
2000	Surveyor		23.5	2.9	73.5			85.7	14.3
	Pratt			32.5	67.5			100.0	
	Welker	35.0	7.5	2.5	55.0			100.0	
2001	Surveyor	11.4	11.4	2.9	74.3	25.0	62.5		12.5
	Welker	21.4		28.6	50.0			100.0	
	Dickens	58.6	20.7		20.7			100.0	
2002	Patton		2.9	11.8	85.3		46.2	53.8	
	Murray	22.7		18.2	59.1		22.2	77.8	
	Durgin	8.3		33.3	58.3		33.3	66.7	

Islands and the Bering Sea, during their younger years, and most return eastward along the continental slope after reaching maturity (Bracken, 1982; Heifetz and Fujioka, 1991). During the migration, young fish which have come from shallower (< 200 m) inshore waters move farther out on the continental shelf and eventually end up as adults in the deeper (> 500 m) waters of the continental slope, which is where spawning takes place.

Ocean circulation patterns can possibly explain the geographic patterns of sablefish releases and recoveries related to GOA seamounts. The route(s) sablefish follow between the continental slope and the seamounts and the depths at which they travel are unknown, but it seems likely that the fish are influenced to some degree by the major current systems of the Gulf of Alaska. Kimura et al. (1998) speculated that sablefish use currents to travel throughout the Gulf of Alaska and up and down North America's west coast.

Circulation in the GOA is driven by the North Pacific subarctic gyre. The southern boundary of the gyre, known as the North Pacific Current, flows eastward, reaching the west coast of North America at about Vancouver Island where it splits into the south-flowing California Current and the north-flowing Alaska Current. The Alaska Current moves north and northwestward on a broad front through the eastern Gulf of Alaska, flowing over the GOA seamounts and up the eastern Gulf coast along the shelf break toward the head of the Gulf (Fig. 9). As the flow leaves the head of the Gulf of Alaska and moves westward, it deepens, narrows to about 100 km, becomes stronger, and is known as the Alaska Stream, or the northern boundary of the subarctic gyre. It runs about 150 km offshore along the Alaska Peninsula and Aleutian Islands, with most of its flow entering the Bering Sea through Near Strait at long. 170°E (Reed and Stabeno, 1993).

The gyre is not circular, but paddle-shaped, with the broad end in the east tapering to the handle in the west. This creates the unusual situation of a close juxtaposition of the east-flowing North Pacific Current with the west-flowing Alaska Stream (Herman et al., 2002). It may also supply a mechanism whereby sablefish that have moved into the deeper waters of the continental slope for spawning might slip into the eastward-flowing North Pacific Current and be carried more or less passively toward the seamounts.

Most of the GOA seamounts lie from 55 to 120 km apart in a line extending more than 740 km, more or less perpendicular to the flow of the North Pacific Current (Fig. 9). Farther to the west, Patton, Cowie, and Murray Seamounts are from 55 to 83 km apart in a line also perpendicular to the current. Several studies describe oceanic features found

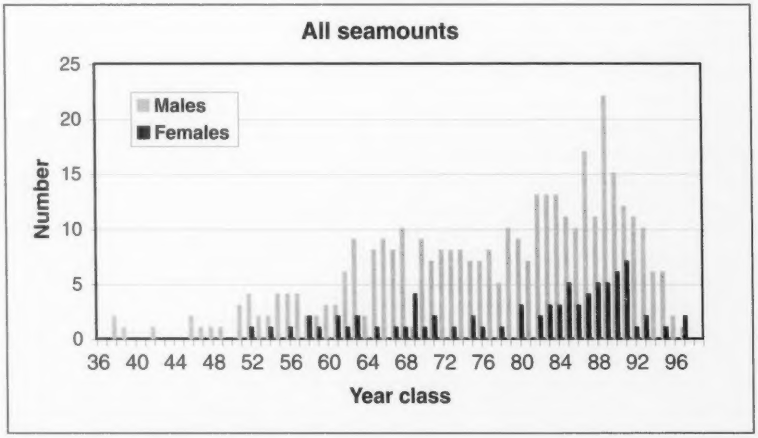


Figure 6.—Numbers by sex of year classes of sablefish present in Gulf of Alaska seamount samples. A total of 440 sablefish were aged.

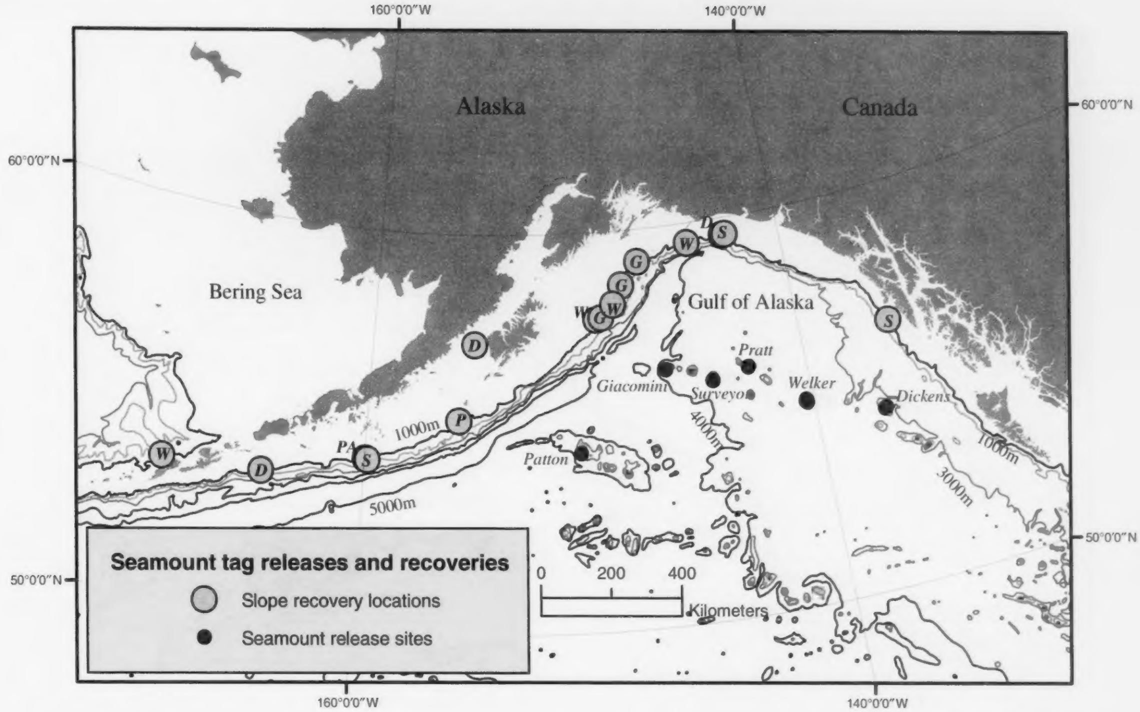


Figure 7.—Slope recovery locations of seamount-tagged sablefish. Letters inside the recovery symbols indicate the seamount of origin. D = Dickens, G = Giacomini, P = Pratt, S = Surveyor, W = Welker, PA = Patton.

in the neighborhood of seamounts that increase the likelihood that sablefish travelling in the North Pacific Current would encounter a seamount in the middle of the GOA. Taylor Columns are eddies of nutrient-rich waters that originate from upwelling of deep ocean waters. The eddies form over seamounts, entrapping the rich waters and increasing productivity in the area of the seamount (Owens and Hogg, 1980; Gould et al., 1981; Dower et al., 1992). Dower and Mackas (1996) describe a "seamount effect" on composition of the zooplankton community up to 30 km from the summit of Cobb Seamount off the Washington coast. Royer (1978) noted the existence of ocean eddies in at least the upper 1,000 m of the water column downstream from seamounts north of Hawaii, and postulated that they were the result of interaction between the North Pacific Current and the seamounts. In modelling studies of oceanic circulation, Hermann et al. (2002) found a clockwise pattern of disturbances around the seamounts. The presence of some or all of these features at each seamount in the line would create an almost unbroken belt of disturbance across the current and greatly increase the chances that sablefish would encounter a seamount.

All of the seven slope-tagged fish recovered on GOA seamounts were tagged and released south or west of Kodiak Island, indicating that they did not strike out for the seamounts during the first part of their westward migration from the eastern GOA. In fact, five of the seven fish were tagged in the Bering Sea or Aleutian Islands, making it likely that the seamount journey began at some point on the return leg of their westward migration, after they had reached maturity (Fig. 8). Sablefish leaving the seamounts would be carried by the same current, here known as the Alaska Current, back to the continental slope. The flow of the current as it passes over the seamounts is back toward the head of the Gulf, so that sablefish using this route would be expected to encounter the slope waters first in the area of the head of the Gulf. Of the 15 slope recoveries with known recovery location, all but 2 were recovered north and west of their seamount release locations. Eight of the 15 fish were recovered between long. 143°W and long. 150°W at the head of the Gulf. Of the remaining 7, 1 was recovered in the Bering Sea, 3 in the western GOA, 2 in the central GOA, and 1 in the eastern GOA (Fig. 7).

Bowie Seamount is directly in line with the North Pacific Current where it reaches the northern British Columbia coast. Fish released in the Bering Sea, Aleutian Islands, and western GOA and recovered on Bowie Seamount may also have travelled there by way of the eastward-flowing North Pacific Current. However, it is likely that Bowie

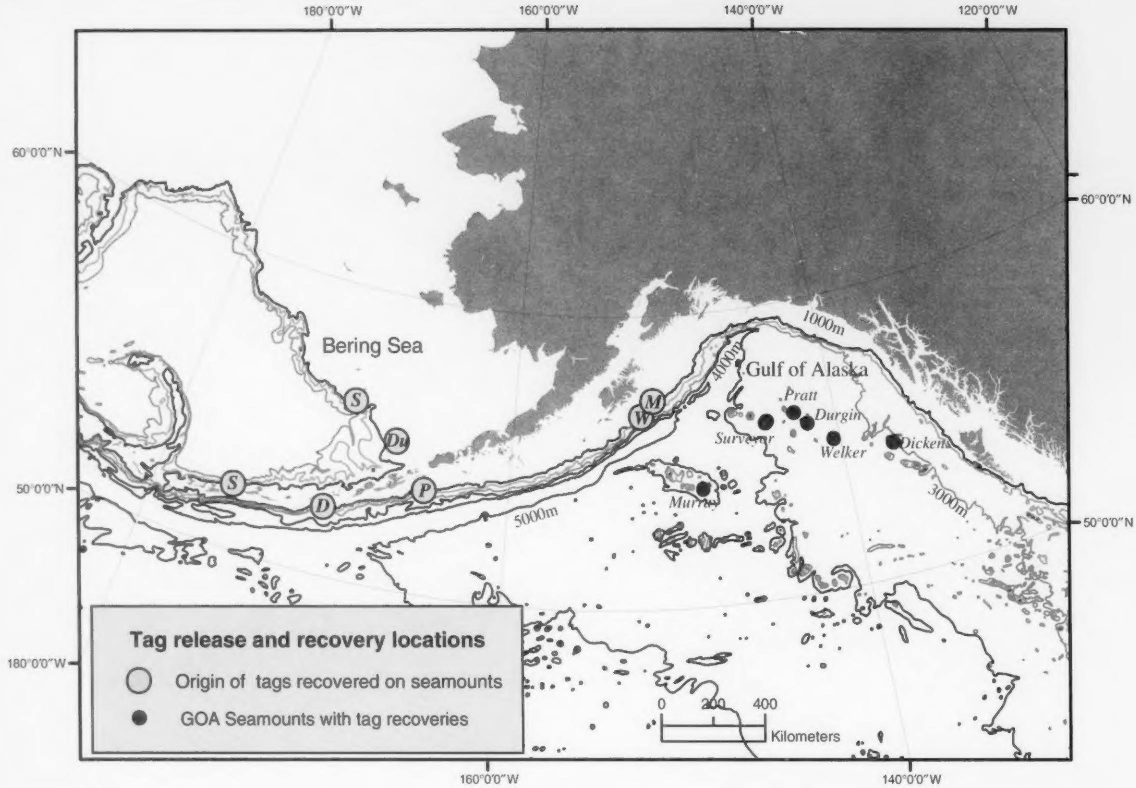


Figure 8.—Seven recovery locations of slope sablefish on Gulf of Alaska seamounts. Letters inside the recovery symbols indicate on which seamount the fish were recovered. D = Dickens, Du = Durgin, M = Murray, P = Pratt, S = Surveyor, W = Welker.

Seamount recoveries originating in the eastern GOA travelled directly to the seamount rather than westward and then eastward by way of the North Pacific Current. Maloney and Heifetz (1997) showed that most sablefish tagged in the inside waters of Chatham or Clarence Strait and most large sablefish tagged in the outside waters of the eastern GOA were recovered in the eastern GOA itself or offshore of British Columbia. Bowie Seamount is only about 185 km off the British Columbia coast, within easy reach for sablefish once they have reached Canadian waters. Water depths between the coast and the seamount are less than those coming from the west, and sablefish travelling from the British Columbia coast to Bowie Seamount may well travel on the bottom to get there.

The population size of sablefish on the GOA seamounts is unknown, but can be inferred to be small based on CPUE or, in the case of Surveyor and Welker Seamounts, the drop in CPUE in successive years of sampling (Table 2). Relatively high catches, as on Welker Seamount in 2000, likely suggest a lack of fishing pressure for a number of years prior to our sampling. The presence of males from 55 of the 61 year classes during 1936–1997 and of females from 33 of those year classes suggests that some travel to the seamounts takes place every year, but there is no way at present to estimate what proportion of the slope population is involved. Likewise, tag recoveries have shown that some fish on the seamounts return to the slope, but it is too soon after tagging to estimate percentages.

Summary

GOA seamount sablefish populations are made up of fish mostly older than 5 years that have migrated from the continental slope, either by way of the North Pacific Current or directly from some point on the slope, either at middepths or on the bottom. The population on each seamount is heavily male-dominant, while the population on the slope is slightly female-dominant. Although seamount males are generally smaller than females, the average age of seamount males is greater than that of seamount females, and males also have a greater range of ages than females. Little or no growth appears to take place in either males or females once the fish arrive on the seamounts.

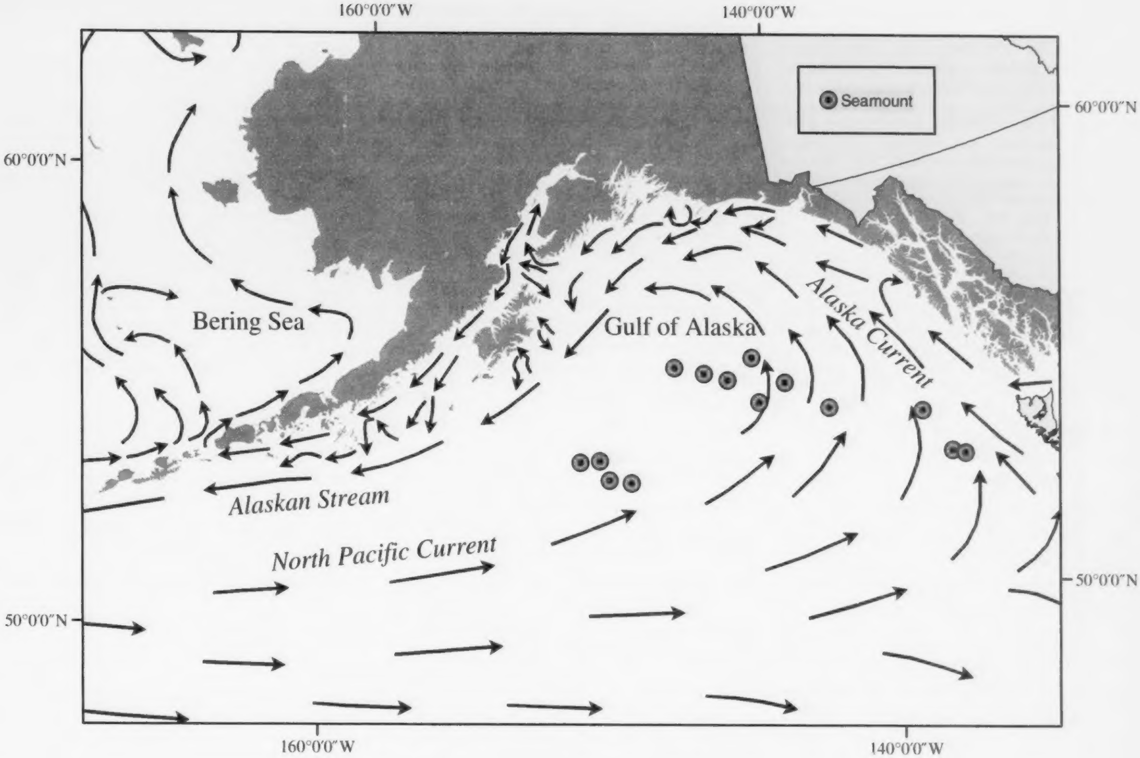


Figure 9.—Circulation in the Gulf of Alaska.

Small populations of sablefish have existed for many years on the GOA seamounts, and they can continue to do so in the absence of concentrated fishing pressure. Many seamounts in both the Atlantic and Pacific Oceans, with larger initial fish populations than the GOA seamounts, have suffered severe declines in these populations after just a few years of concentrated fishing (Clark, 1999; Koslow et al., 2001). The GOA seamounts, isolated out in the middle of the Gulf of Alaska, have been only occasionally fished and are still relatively unspoiled. In 2005, the North Pacific Fishery Management Council declared 16 named seamounts within the EEZ off Alaska to be Alaska Seamount Habitat Protection Areas. Most of these seamounts are in the GOA and the total area involved is 5,329 nmi^2. In these areas, all bottom-contact fishing (longlines, trawls, or pots) by Council-managed fisheries, including sablefish, is prohibited.

Acknowledgments

I thank Mike Sigler, Phil Rigby, and Jon Heifetz for reviews and helpful comments. I also thank Delsa Anderl of the NMFS Alaska Fisheries Science Center's Age and Growth Program in Seattle, Wash., who aged all of the sablefish in this 4-year study. Special thanks go to the captains and crews of the F/V *Ocean Prowler* and F/V *Alaskan Leader* for their great assistance in the collection of data for this study in the summers of 1999–2002.

Literature Cited

Alton, M. S. 1986. Fish and crab populations of Gulf of Alaska seamounts. *In* R. N. Uchida, S. Hayasi, and G. W. Boehlert (Editors), Environment and resources of seamounts in the North Pacific, p. 45–51. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 43.

Beamish, R. J., and D. E. Chilton. 1982. Preliminary evaluation of a method to determine the age of sablefish (*Anoplopoma fimbria*). Can. J. Fish. Aquat. Sci. 39:277–287.

Bracken, B. E. 1982. Sablefish (*Anoplopoma fimbria*) migration in the Gulf of Alaska based on gulf-wide tag recoveries, 1973–1981. Alaska Dep. Fish Game Inf. Leafl. 199, 24 p.

Clark, M. 1999. Fisheries for orange roughy (*Hoplostethus atlanticus*) on seamounts in New Zealand. Oceanol. Acta 22:5993–6020.

Dower, J., H. Freeland, and K. Juniper. 1992. A strong biological response to oceanic flow past Cobb Seamount. Deep-Sea Res. 39:1139–1145.

________ and D. Mackas. 1996. "Seamount effects" in the zooplankton community near Cobb Seamount. Deep-Sea Res. 43:837–858.

Fujioka, J., F. Shaw, G. McFarlane, T. Sasaki, and B. Bracken. 1988. Description and summary of the Canadian, Japanese, and U.S. joint database of sablefish tag releases and recoveries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-137, 34 p.

Gould, W., R. Hendry, and H. E. Huppert. 1981. An abyssal topographic experiment. Deep-Sea Res. 28:409–440.

Heifetz, J., and J. Fujioka. 1991. Movement dynamics of tagged sablefish in the northeastern Pacific. Fish. Res. 11:355–374.

Hermann, A. J., D. Haidvogel, E. Dobbins, and P. Stabeno. 2002. Coupling global and regional

circulation models in the coastal Gulf of Alaska. Prog. Oceanogr. 53:335–367.

Hughes, S. E. 1981. Initial U.S. exploration of nine Gulf of Alaska seamounts and their associated fish and shellfish resources. Mar. Fish. Rev. 42(1):26–33.

Kimura, D., A. Shimada, and F. Shaw. 1998. Stock structure and movement of tagged sablefish, *Anoplopoma fimbria*, in offshore northeast Pacific waters and the effects of El Nino-Southern Oscillation on migration and growth. Fish. Bull. 96:462–481.

Koslow, J., G. Boehlert, J. Gordon, R. Haedrick, P. Lorance, and N. Parin. 2001. The impact of fishing on continental slope and deep-sea ecosystems. ICES J. Mar. Sci. 57:548–557.

Maloney, N., and J. Heifetz. 1997. Movements of tagged sablefish released in the eastern Gulf of Alaska. *In* M. E. Wilkins and M. W. Saunders (Editors), Biology and management of sablefish, *Anoplopoma fimbria*, p. 115–121. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 130.

Mason, J., R. Beamish, and G. McFarlane. 1983. Sexual maturity, fecundity, spawning, and early life history of sablefish (*Anoplopoma fimbria*) in waters off the Pacific coast of Canada. *In* Proceedings of the International Sablefish Symposium, p. 137–140. Alaska Sea Grant Rep. 83-8, Univ. of Alaska, Fairbanks.

Murie, D., M. Saunders, and G. McFarlane. 1996. Canadian trap-fishery for sablefish on seamounts in the northeastern Pacific Ocean, 1983–1993. Can. Manuscr. Rep. Fish. Aquat. Sci. 2348, 105 p.

Owens, W., and N. Hogg. 1980. Oceanic observations of stratified Taylor columns near a bump. Deep-Sea Res. 27:1029–1045.

Reed, R., and P. Stabeno. 1993. The recent return of the Alaskan Stream to Near Strait. J. Mar. Res. 51:515–527.

Royer, T. 1978. Ocean eddies generated by seamounts in the North Pacific. Science 199:1063–1064.

Sasaki, T. 1983. Relative abundance and size structure of sablefish in the eastern Bering Sea, Aleutian region and Gulf of Alaska based on the results of Japan-U.S. joint longline surveys from 1979 to 1982. *In* Proceedings of the International Sablefish Symposium, p. 239–253. Alaska Sea Grant Rep. 83-8, Univ. of Alaska, Fairbanks.

Shaw, F., and N. Parks. 1997. Movement patterns of tagged sablefish recovered on seamounts in the N.E. Pacific Ocean and Gulf of Alaska. *In* M. E. Wilkins and M. W. Saunders (Editors), Biology and management of sablefish, *Anoplopoma fimbria*, p. 151–158. U.S. Dep. Commer., NOAA Tech Rep. NMFS 130.

Sigler, M. 1994. An electronic measuring board with bar codes. Trans. Am. Fish. Soc. 123: 115–117.

Rangia and Marsh Clams, *Rangia cuneata*, *R. flexuosa*, and *Polymesoda caroliniana*, in Eastern México: Distribution, Biology and Ecology, and Historical Fisheries

ARMANDO T. WAKIDA-KUSUNOKI and CLYDE L. MacKENZIE, Jr.

Introduction

People have gathered Rangia and marsh clams along the eastern México coast (Fig. 1) since prehispanic times. The clam species are almeja gallo or rooster clam, *Rangia cuneata*; almeja casco or helmet clam, *R. flexuosa;* and almeja negra o prieta or black clam, *Polymesoda caroliniana* (Fig. 2). They form the basis for the most important clam fishery on this coast. Next to them in importance is the southern quahog, *Mercenaria campechiensis* (MacKenzie et al., 2002). *Rangia cuneata* is the principal species targeted by fishermen and has the highest economic value. *Rangia flexuosa* and *P. caroliniana* at times are targeted for harvesting, but many are retained for sale when harvested with *R. cuneata* (Ruiz, 1975; Baqueiro and Echevarría, 1997).

This paper describes the distribution, biology, and ecology of the Rangia and marsh clams as well as their harvests and marketing as food. The information was obtained from the literature and by interviewing clam industry fishermen, processors, managers of cooperatives, and government technicians, and by photographing relevant scenes in the States of Tamaulipas, Veracruz, Tabasco, and Campeche during 2004 and 2005.

Armando T. Wakida-Kusunoki is with the Instituto Nacional de la Pesca, Ave. Héroes del 21 de Abril s/n, Col. Playa Norte, Cd del Carmen, Campeche. C.P. 24120. México. (e-mail: armandowakida@yahoo.com.mx), and Clyde L. MacKenzie, Jr., is with the James J. Howard Marine Science Laboratory, Northeast Fisheries Science Center, National Marine Fisheries Service, NOAA, 74 Magruder Road, Highlands, NJ 07732.

ABSTRACT—Rangia and marsh clams, Rangia cuneata, R. flexuosa, *and* Polymesoda caroliniana, *occur in brackish waters along México's eastern coast from the northern State of Tamaulipas to the southern State of Campeche. The clams were important to the prehispanic people in the southern part of the State of Veracruz, where they were used as food and as construction material. In modern times, they are harvested for food. The fishermen wade in shallow water and harvest the clams in soft sediments by hand. Annual landings of whole clams during a recent 5-yr period, 1998–2002, were 1,139–1,695 t. The only area with a substantial ongoing clam fishery is in the Lower Papaloapan River Basin, including Alvarado Lagoon, where as many as 450 fishermen are licensed harvesters. This fishery for the Rangia and marsh clams is the most important clam fishery along México's Gulf Coast.*

Distribution, Biology, and Ecology

Rangia cuneata ranges from Chesapeake Bay, Maryland, to México's Terminos Lagoon, and *R. flexuosa* is found from Louisiana to Terminos Lagoon, while *P. caroliniana* ranges from Virginia to the State of Campeche (Abbott, 1974; Ruiz, 1975). The two *Rangia* species and *P. caroliniana* are present in at least 16 estuaries along México's Gulf Coast from the States of Tamaulipas to Campeche (Table 1). Their main production area is in the Alvarado Lagoon and other small lagoons and channels that are part of the lower Papaloapan River area. Minor harvesting takes place in the Mezcalapa Lagoon and Tamiahua Lagoon, both in Veracruz (Echeverria et al., 2002).

Rangia cuneata and *P. caroliniana* have about the same shell length, 3–7 cm, when harvested, while *R. flexuosa* is smaller, 2.5–4 cm (Garcia-Cubas, 1981). Their valves are hard, subtriangulate, and inequilateral; their color ranges from black to light brown or yellowish. Their periostracum is fibrous and is usually eroded near the umbos which have a salmon-pink color. The shell interior is bluish white and the dorsal part is pinkish, sometimes with purple spots. The pallial line is tenuous (Garcia-Cubas, 1981). In *R. cuneata*, the posterior lateral tooth is long (LaSalle and De la Cruz, 1985). *Rangia flexuosa* is easily distinguished from *R. cuneata* by its short posterior lateral tooth (Garcia-Cubas, 1981). The three species occur in brackish waters. *Rangia cuneata* is most common in areas with salinities from 5–15‰ (Swingle and Bland, 1974). Its habitats have high water turbidity and soft substrates that consist of a mixture of sand, mud, and vegetation (Tarver, 1972). Its highest concentrations are in shallow areas less than 6 m deep. A decrease in density has been observed as depth increased from 2.5 to 4.6 m (LaSalle and De la Cruz, 1985). The two *Rangia* species inhabit subtidal zones, whereas *P. caroliniana* occurs in intertidal areas and in relatively small numbers in the shallow nearshore areas.

The feeding of *R. cuneata* and *P. caroliniana* is suspensivore and saprophytic, while *R. flexuosa* is microphagous, suspensivore, and saprophytic (Olsen, 1973, 1976; Garcia-Cubas, 1981). *Rangia cuneata* appears to obtain organic matter

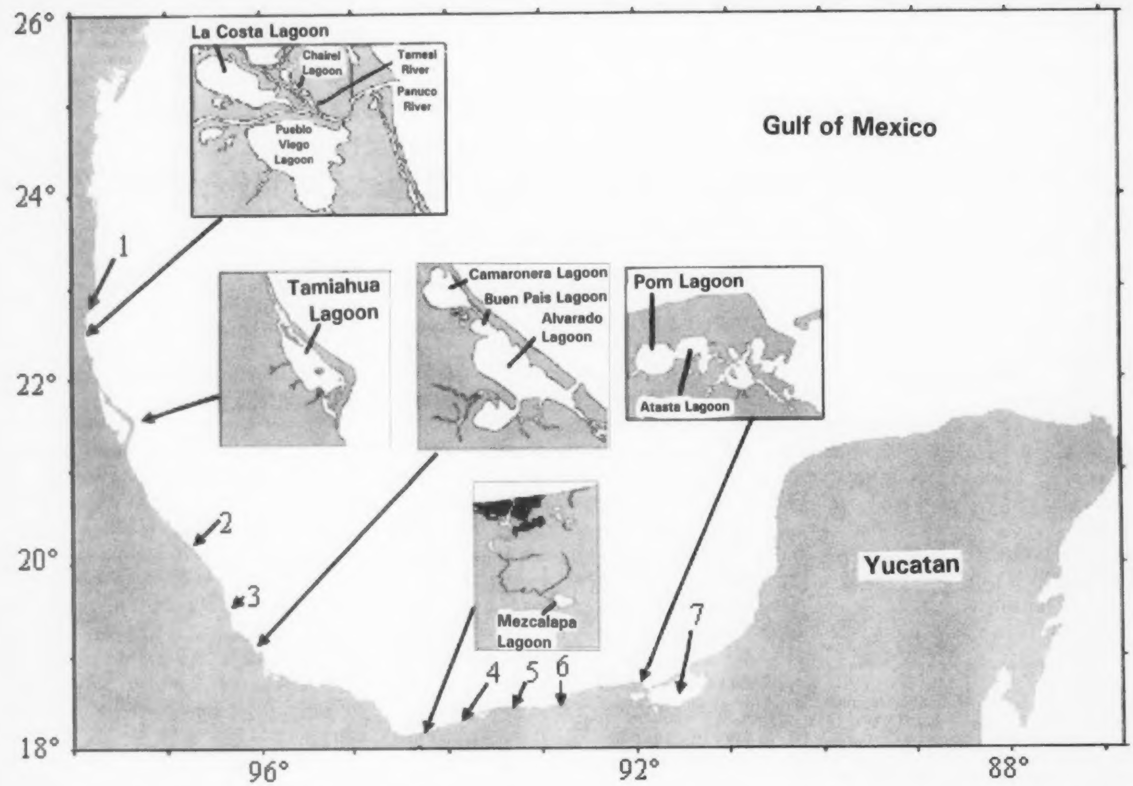


Figure 1.—Locations where Rangia and marsh clams are most abundant in eastern México. The numbers refer to the following lagoons: 1) San Andres Lagoon, 2) Grande and Chica Lagoons, 3) La Mancha Lagoon, 4) Carmen and Machona Lagoons, 5) Tupilco Lagoon, 6) Mecoacan Lagoon, and 7) Terminos Lagoon.

and phosphate from sediments by direct ingestion or by feeding on bacteria associated with the materials (Tenore et al., 1968).

In some zones of the Alvarado Lagoon, the mean density of *R. cuneata* was about 29/m^2; *R. refluosa*, 34/m^2; and *P. caroliniana*, 15/m^2 (Morales and Cruz Suáres, 2000). In Mezcalapa Lagoon, the *R. cuneata* density was 15/m^2 and *P. caroliniana* was 15/m^2 (Morales, 2004). The densities are lower than those reported in the United States, where harvesting does not occur: *R. cuneata* had a density of 26/m^2 in Lake Pontchartrain, Louisiana (Abadie and Poirrier, 2000); and 100/m^2 in a Mississippi marsh (Duobinis-Gray and Hackney, 1982). The lower densities in México may be due to commercial harvesting there.

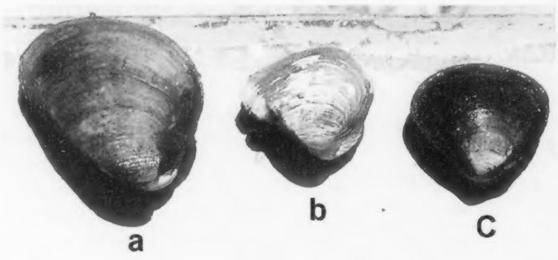


Figure 2.—A) Rooster clam, *Rangia cuneata*; B) helmet clam, *Rangia flexuosa*; and C) black clam, *Polymesoda caroliniana*. Photograph by Armando T. Wakida-Kusunoki.

In Alvarado Lagoon, *R. cuneata* spawn year-round, but mostly from February–July (Echeverria and Rodriguez, 1993). In Pom Lagoon, Campeche, where temperatures range from 22.0 to 30.5°C and salinities in summer are from 0 to 3‰, their spawning is during February–June and September–November (Rogers and Garcia-Cubas, 1981; Ortega-Salas, 1992).

During the summer rainy season, fresh water from coastal swamps enters Alvarado Lagoon and can reduce the salinity to nearly zero causing some of the clams to die (Garcia[1]). The epibiota on any clam shells lying on sediment surfaces include mollusks, barnacles, and tubicular polychaetes.

In México, *R. cuneata* is preyed upon by fish, including blue catfish, *Ictalurus furcatus;* freshwater drum, *Aplodinotus grunnieus;* spot, *Leiostomus xanthurus;* and also blue crabs, *Callinectes* spp., river shrimp, *Macrobrachium* spp., gastropods (including moon snails, *Polinices* spp.), and ducks, family: Anatidae. Within its overall range in the United States and México, *R. cuneata* is eaten by at least 17 fish species, 2 crab species, 2 gastropod species, and 8 duck species (references cited in LaSalle and De la Cruz, 1985).

Table 1.—Méxican lagoons where brackish water clams are reported.

State/lagoon	Brackish water clams	References
Tamaulipas		
San Andres	PC[1]	Covarrubias, 1988; Garcia-Cubas et al., 1990a
Chairel and Tamesi River	PC	Personal observation
Veracruz		
La Costa	PC	Segura, 1980
Pueblo Viejo	RF[2], PC	Reguero and Garcia-Cubas, 1993
Tamiahua	RC[3], RF	Garcia-Cubas, 1978; Gomez, 1984; Arroyo et al., 1985; Arroyo and Ortega, 1987; Portilla,1989; Echeverria et al., 2002
Tampamachoco	RF, RC	Reguero et al., 1991; Flores and Garcia-Cubas, 1986
La Mancha	RF	Flores-Andolais et al., 1988
Chica and Grande	RF	Garcia-Cubas et al., 1992
Camaronera	RF, RC	Reguero and Garcia-Cubas, 1991
Alvarado	RF, RC, PC	Reguero and Garcia-Cubas, 1989; Echeverria et al., 2002
Sontecomapan	RC, RF	Garcia-Cubas and Reguero, 1995
Mezcalapa	RC, PC	Echeverria et al., 2002; Morales, 2004
Tabasco		
Carmen-Machona	RF, RC, PC	Antoli and Garcia-Cubas, 1985
Tupilco-Ostón	RF	Garcia-Cubas and Reguero, 1990
Mecoacan	RF, RC	Garcia-Cubas et al., 1990b
Campeche		
Terminos system: Pom, del Este, Balchacan, and Panlau	RC, RF, PC	Garcia-Cubas, 1981

[1] PC=*Polymesoda caroliniana.*
[2] RF=*Rangia flexuosa.*
[3] RC=*Rangia cuneata.*

Historical Uses

Prehispanic people in southeastern México used the meats of the clams for food and their shells as construction material (Stark, 1977, 2001; Stark[2]). Ethnographers have noted the use of the clams as the primary material of cement in southern Veracruz (Stark[2]). Jimenez Badillo (1991) found evidence that the shells of *R. flexuosa* and *P. caroliniana* were carried inland and used as offerings in the Templo Mayor (main temple) of Tenochtitlan (prehispanic México City).

In recent decades, the clams have been harvested at least lightly along the entire coast from Laguna Madre in Tamaulipas to Terminos Lagoon in Campeche (Baqueiro and Echevarría, 1997), but currently nearly 99% of the commercial landings are from Alvarado Lagoon. In the early 1980's, Pom Lagoon, Campeche, was the major clam producing area, but its stocks have declined in abundance. Sediments in Pom Lagoon range from silty sand to silty clay.

In Pom Lagoon, clams were harvested from boats with scrape (dip) nets, which consisted of a wooden pole 3–5 m long that had at one end a rectangular metal frame with attached mesh bag. The frame was 50 cm wide and 20 cm high; the mesh size was 1.5 cm (Fig. 3). To gather the clams, the fishermen anchored their boats, and pushed their scrape nets 10–15 cm into the soft bottom, then pulled the nets toward themselves through the sediments, lifted the nets, rinsed out the sediments, and finally brought them into the boats and emptied the clams into containers (Fig. 4, 5).

Figure 3.— Fisherman with scrape net for harvesting Rangia and marsh clams in Pom Lagoon, Campeche, 1985. Photograph by Victor A. Rivera Roman.

After the fishermen harvested like this for several years, the clams became scarcer. To maintain their catches, the fishermen modified their method by pushing the scrape nets into the bottom sediments, tying the end of the poles to their boats, and dragging them behind

[1] Garcia M., S. Clam fisherman, Alvarado, Veracruz. Personal commun., July 2004.

[2] Stark, B. L. Professor, Arizona State University, Personal commun., March 2004.

Figure 4.—Fishermen harvesting Rangia and marsh clams with scrape nets in Pom Lagoon, Campeche, 1985. Photograph by Victor A. Rivera Roman.

Figure 6.—The plastic box is supported at the water surface by Styrofoam and is nearly full of Rangia and marsh clams, Alvarado Lagoon. Rubber balloons cover the fisherman's fingers. Photograph by Armando T. Wakida-Kusunoki.

Figure 5.— Fishermen in Pom Lagoon unloading their Rangia and marsh clams, 1985. Photograph by Victor A. Rivera Roman.

for several minutes to fill the nets with clams (Baqueiro and Echeverria, 1997). In 1981, about 310 people harvested *R. cuneata* in Campeche (Uribe-Martinez, 1983). Since the middle of the 1990's, the State of Veracruz has far exceeded Campeche in clam landings.

Current Harvesting Gear and Methods

About 450 people are licensed to harvest clams in Alvarado Lagoon (personal commun. SAGARPA). The numbers who actually harvest in any one day are undocumented. Most harvesters are men, 18–50 years old, but some women and children harvest also. Nearly all clam fishermen work individually, as few belong to cooperatives. They have relatively low incomes, about 200 pesos (US$18.75)/day.

Fishermen go to and from the Alvarado Lagoon harvesting beds in wood and fiberglass boats. The boats, about 7.6 m long, are propelled by 45–60 hp outboard motors, and each carries up to nine fishermen. Clam buyers share boat expenses (costs of motors and fuel) with the fishermen.

Fishermen know the locations where each of the clam species is most abundant, and they harvest the species requested by the buyer. Harvests are by hand picking. The fishermen cover their fingers with small latex balloons to protect them against cuts from shells (Fig. 6). They leave their boats to wade in the water and feel for the clams in the bottom sediments with their fingers (Fig. 7). The clams are placed in floating plastic boxes tethered with a thin line to the clammers' waists (Fig. 8). They harvest each day for about 5 h (usually from about 9 a.m.–2 p.m.). Each gathers about 60 kg (1,500 clams)/day (Garcia[1]). Fishermen sort the clams, putting the *R. cuneata*, *R. flexuosa*, and *P. caroliniana* into separate bags on board the boats before they arrive ashore (Fig. 9, 10, 11). The largest harvests are between September and February. They decrease after the lenten season, because the demand for clams falls.

In the De La Costa Lagoon, Tamesi River, and Chairel Lagoon near Tampico, Tamaulipas, two or three fishermen harvest clams for sale (Fig. 12, 13). In this area, the most common species harvested is *P. caroliniana*.

Landing Statistics

Official statistics gathered by México's Federal government lump together all the clam species[3] (Mackenzie et al., 2002), and therefore landings of the different species of brackish water clams cannot be determined (Fig. 14). Pech et al. (1995) reported that the landings composition in Alvarado Lagoon were about 50% *R. cuneata*, 33% *R. flexuosa*, and 17% *P. caroliniana*. During the period 1985–2002, annual production of clams ranged from 624 to 2,945 t, with an average of 1,299 t. Campeche landings fell from 1,389 t/year to less than 100 t/year from 1985 to 2002, while Veracruz landings increased from an average of 377 t/year during 1985–1988 to 1,389 t/year during 1990–1992.

The production decline in Campeche may have been caused by increased harvest owing to the México government-

[3] CONAPESCA. 2002. Anuario estadistico de pesca. SAGARPA (Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentación). http://www.sagarpa.gob.mx/conapesca/planeacion/anuario2002.

Figure 7.—Harvesting Rangia and marsh clams in Alvarado Lagoon. Photograph by Armando T. Wakida-Kusunoki.

Figure 8.—Floating box full of Rangia and marsh clams, Alvarado Lagoon. Photograph by Armando T. Wakida-Kusunoki.

Figure 9.—Sorting the species of Rangia and marsh clams, Alvarado Lagoon. Photograph by Armando T. Wakida-Kusunoki.

Figure 10.—Fishermen unloading their harvests of clams, Alvarado Lagoon. Photograph by Armando T. Wakida-Kusunoki.

ment raising harvest quotas from 20 to 34 t/week. The market-sized clams may have been depleted. Besides harvesting, though, environmental changes that resulted from bottom dredging when a gas pipeline was installed in the Pom Lagoon may have been partly responsible for the reduced abundance of the clams in Campeche (Solis-Ramirez, 1994; Baqueiro and Echeverria, 1997). Similar abundance declines of *R. cuneata* occurred in other estuaries where shell dredging or construction and improvements of deepwater navigation channels have taken place (Harrel, 1993; Abadie and Poirrier, 2000).

Marketing

Rangia and marsh clams have a muddy taste and thus people do not eat them often. Fishermen's families eat them about once a week. The clams are prepared in soups containing boiled rice and in cocktails (Garcia[1]). The soups may also include blue crabs, shrimp, oysters, fish, or squid, besides the clams. This is a traditional food preparation in Alvarado and has the name, "arroz a la tumbada."

Nearly all the harvested clams are trucked to México City, while small quantities are distributed to markets in Veracruz City and in towns nearby in Veracruz (Morales[4]). Brackish water clams are sold in the shell by weight. Buyers prefer *R. cuneata* with shell lengths of 2–5 cm. In 2004, buyers paid fishermen 8.00–10.00 pesos (US$0.70–0.86)/kilo(25–30 clams) for *R. cuneata* and 1.50–2.00 pesos (US$0.13–0.17)/kilo(30–40 clams) for *R. flexuosa* and *P. caroliniana* (20–30 clams). The clams are sold in food markets and outdoor fish markets in México City. *Rangia cu-*

[4]Morales, R. Technician, Centro Regional de Investigación Pesquera, Veracruz. Personal commun., July 2004.

Figure 11.—Hut where fishermen keep their bags of Rangia and marsh clams, Alvarado Lagoon. Photograph by Armando T. Wakida-Kusunoki.

Figure 12.—Fisherman rinsing mud and sand from his Rangia and marsh clams, Tamesi River, Tamaulipas. Photograph by Armando T. Wakida-Kusunoki.

Figure 13.—Fisherman unloading his daily harvest of Rangia and marsh clams, Tamesi River, Tamaulipas. Photograph by Armando T. Wakida-Kusunoki.

neata are sold to the wholesale trade for 18.28 pesos (US$1.60)/kilo whereas *R. flexuosa* and *P. caroliniana* sell for 7.15 pesos (US$0.62)/kilo (Anonymous[5]). In public markets, *R. cuneata* frequently sell for 18–25 pesos (US$1.55–2.20)/kilo, while *R. flexuosa* and *P. caroliniana* sell for 6–9 pesos (US$0.68–0.70) (SIIM, 2004). In markets in Ciudad Del Carmen, Tabasco, and Veracruz City, marsh clams sell for 11.1–13.9 pesos (US$0.90–1.25)/kilo. The price of a typical plate of seafood soup with rice, including four clams with other fish products, is about 60 pesos (US$5.22) in a restaurant in the city of Alvarado, Veracruz. The clams are used also in preparing "paella," a traditional Spanish-culture dish.

[5]Anonymous. 2004. Mollusks, cephalopods y rajas congealed. www.infopesca.org/libres/info10 2004/Moluscos.pdf

Future Prospects

The Méxican Government increased its financial support of fishermen groups to carry out development projects beginning in 2003. Clam fishermen are encouraged to propose ideas and marketing strategies to increase their incomes. The goal is to improve economic conditions in the fishing villages.

More information is needed about the ecology of the brackish water clams as an aid in increasing and maintaining their production. Future research should concentrate on a better understanding of 1) conditions surrounding recruitment, 2) predation upon the clams, and 3) the ecological requirements of each clam species. Clam production might be increased by making population-abundance surveys in all the coastal lagoons, to determine whether high abundances of clams are present in them.

Southern Quahog Fishery

Southern quahogs also occur in some of the same estuaries as the Rangia and marsh clams, but only in high salinity areas (MacKenzie et al., 2002). They are most abundant in Laguna Madre, Tampamachoco Lagoon, Carmen Lagoon, Tupilco Lagoon, Mecoacan Lagoon, Terminos Lagoon, and near Isla Arena. They are harvested on a commercial scale mainly in Carmen Lagoon. Fishermen harvest them at wading depths. They feel for the quahogs with their feet, collect them by hand, and place them in plastic boxes that are floated by empty soda bottles and Styrofoam similar to those used in the Rangia and marsh clam fishery. Each fisherman

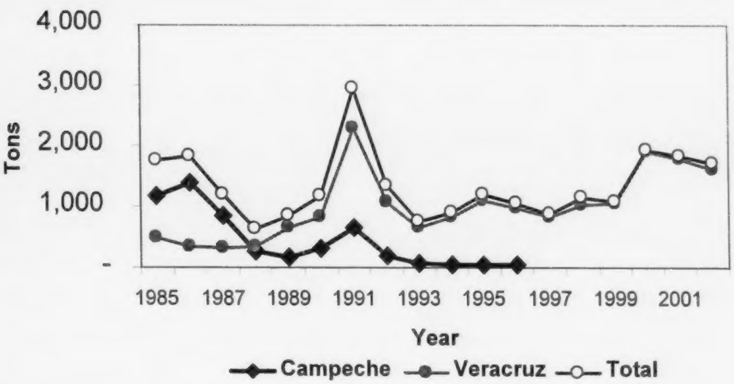


Figure 14.—Landings of clams (whole weight in tons) by state in eastern México (text footnote 3).

usually gathers 200–250 quahogs/day. The quahogs are sold whole and then shipped by truck on a small scale to various cities, where they usually are served in cocktails, in soups, or in their shells after being broiled.

Acknowledgments

We thank Alejandro Gonzalez Cruz and Rodolfo Morales for their help as guides in tours of clamming areas and for providing information, Victor Rivera Roman for providing photographs, Victor G. Burrell, Jr., Dexter S. Haven, and Fernando T. Wakida, for useful comments on earlier drafts of the manuscript, and the other people who provided information.

Literature Cited

Abadie, S. W., and M. A. Poirrier. 2000. Increased density of large Rangia clams in Lake Pontchartrain after the cessation of shell dredging. J. Shellfish Res. 19(1):481–485.

Abbott, R. T. 1974. American seashells. Van Nostrand Reinhold Co. N.Y., 663 p.

Anatoli, V., and A. Garcia-Cubas. 1985. Systematics and ecology of mollusks in the coastal lagoons of Carmen y Machona, Tabasco, México. An. Inst. Cienc. del Mar y Limnol. Univ. Nac. Auton. México 12(1):145–198.

Arroyo H., J. and S. Ortega. 1985. Abundancia y distribución de moluscos bentónicos en la laguna de Tamiahua, Ver., México. Memorias de la VIII Congreso Nacional de Zoología. Saltillo, Coahuila, México, p. 704–718.

________ and ________. 1987. Aspectos de la comunidad de gasterópodos y pelecípodos de la Laguna de Tamiahua, Ver., México 1987. Memorias del IX Congreso Nacional de Zoología. Villahermosa, Tabasco, México, 240 p.

Baqueiro, E., and V. Echeverría. 1997. Bivalve fisheries. *In* P. Flores-Hernández, J.C. Seijo Sánchez-Gil, and F. Arreguín-Sanchez (Editors), Analysis and Diagnostic of critical fisheries resources of Gulf de México, p. 19–25. Univ. Autónoma de Campeche. EPOMEX Sci. Ser. 7.

Covarrubias, A. E. 1988. Estudio Preliminar de la fauna malacológica de la Laguna Costera de San Andrés, Tamaulipas. Bachelor's thesis. Fac. Ciencias, Univ. Nacional Autónoma de México, 75 p.

Duobinis-Gray, E. M., and C. T. Hackney. 1982. Seasonal and spatial distribution of the Carolina marsh clam *Polymesoda caroliniana* (Bosc) in a Mississippi tidal marsh. Estuaries 5(2):102–109.

Echeverría, R. V. S., and A. Torres G. 1991. Informe final de proyecto estudio biológico pesquero de la almeja Rangia cuneata en la cuenca baja del Río Papaloapan. Informe Técnico, CRIP, Veracruz. Instituto Nacional de la Pesca, 16 p.

________ and R. Rodriguez. 1993. Informe final correspondiente al recurso almeja Rangia cuneata en la cuenca baja del Rio Papaloapan. Informe Técnico, CRIP, Vera Cruz, 13 p.

________, J. A. Pech-Paat, E. Baqueiro-Cárdenas, and C. Re Regis. 2002. La pesquería de Almeja. *In* A. Guzmán, C. Quiroga B., C. Díaz L., C. Contreras, and G. Silva L. (Editors), La pesca en Veracruz y sus perspectivas de desarrollo, p. 229–232. Inst. Nacional de la Pesca y Univ. Veracruzana. Veracruz, Veracruz.

Flores A., F. and A. Garcia-Cubas. 1986. Ecology and systematic of the mollusks from the Sontecomapan Lagoon, Veracruz, México. Memoirs of 3rd National Meeting of Malacology and Conchology. Monterrey, Nuevo Leon México, p. 48–68.

Flores-Andolais, A., Garcia Cubas A., and A. Toledano G. 1988. Systematic and ecological aspects of the mollusks from La Mancha Lagoon, Veracruz, México. An. Inst. Cienc. del Mar y Limnol. UNAM 15(2):235–258.

Garcia-Cubas, A. 1978. Ecologia y distribucion de los micromoluscos de tres lagunas litorales del Golfo de México. Doctoral thesis. Dpto de Biología. Fac. Ciencias. UNAM, 256 p.

________. 1981. Mollusks of a tropical system in the southern Gulf of México (Laguna de Terminos, Campeche). An. Inst. Cienc. del Mar y Limnol. Univ. Nac. Autón. México, Publ. Esp., 5, 182 p.

________, A. Covarrubias, and M. Reguero. 1990a. Aspectos ecológicos de moluscos de aguas marinas y salobres de la Laguna Costera de San Andrés, Tamaulipas. Memorias del 4[ta] Reunion Nacional de Malacologíay Conquiliologia. La Paz, Baja California, México.

________, F. Escobar de la llata, L.V. Gonzalez-Ania, and M. Reguero. 1990b. Mollusks of Mecoacan, Tabasco, México: Systematics and ecology. An. Inst. Cienc. del Mar y Limnol. Univ. Nac. Autón. México 17(1):1–30.

________ and M. Reguero. 1990. Mollusks of lagunar system of Tupilco-Ostión, Tabasco, México: Systematic and ecology. An. Inst. Cienc. del Mar y Limnol. Univ. Nac. Autón. México 17(2):309–343.

________ and ________. 1995. Moluscos de la Laguna Sontecomapan, Veracruz, México: Sistemática y ecologia. Hidrobiológica 5:1–24.

________, ________, and R. Elizarraras. 1992. Mollusks from Chica-Grande System, Veracruz, México: Systematics and ecology. An. Inst. Cienc. del Mar. y Limnol. UNAM 19(1):71–121.

Gomez Ortiz, G. 1984. Contribución al estudio de la biología pesquera de almeja gallito (Rangia cuneata Gray) en los esteros Cucharas y Tancochín, Ver., México. Bachelor's thesis. Univ. del Noroeste. Tampico, Tamaulipas.

Harrel, R. C. 1993. Origin and decline of the estuarine clam Rangia cuneata in the Neches River. Texas. Am. Malacol. Bull. 10(2):153–159.

Jiménez Badillo, D. 1991. Malacología del Templo Mayor a partir de los datos de la ofrenda H. *In* O. J. Polanco, La fauna en el Templo Mayor. GV Editores-Asociación de Amigos del Templo Mayor. Colección Divulgación, México, p. 171–211.

LaSalle, M. W., and A. A. de la Cruz. 1985. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Gulf of México)—common rangia. U.S. Dep. Inter., Fish Wildl. Serv., Biol. Rep. 82(11.31). U.S. Army Corps Eng. TR EL-82-4, 16 p.

MacKenzie, C. L., Jr., A. Morrison, D. L. Taylor, V. G. Burrell, Jr., W. S. Arnold, and A. T. Wakida-Kusunoki. 2002. Quahogs in eastern North America: Part II, history by province and state. Mar. Fish. Rev. 64(3):1–64.

Morales, H. R. 2004. Estudio sobre la abundancia de almejas de Agua dulce en la Laguna de Mezcalapa, Mpio. de Minatitlán, Ver. Informe Tecnico. Inst. Nacional de la Pesca, 6 p.

________ and E. R. Cruz Suáres. 2000. Estudio sobre la abundancia de almejas de Agua dulce en la zona de pesca de la Coop. Pescadores Unidos de Alvarado. Instituto Nacional de la Pesca. Informe Tecnico, 7 p.

Olsen, L. A. 1973. Food and feeding in relation to the ecology of two estuarine clams, *Rangia cuneata* (Gray) and *Polymesoda caroliniana* (Bose). M.S. Thesis. Florida State University, Tallahassee, 102 p.

________. 1976. Ingested material in two species of estuarine bivalves: *Rangia cuneata* (Gray) and Polymesoda caroliniana (Bose). Proc. Natl. Shellfish. Assoc. 66:103–104 (Abstract).

Ortega-Salas, A. A. 1992. An estimation to calculate the rate of growth of the clam, Rangia cuneata, at the southeast of México. Rev. Soc. Mex. Hist. Nat. 43:109–113.

Pech, P. J. A., V. S. Echeverría-Reyes, I. Aguilar C., C. Morales D., R. Rodríguez R., A. Torres G., and A. Chávez G. 1995. Diagnóstico del recurso almeja en el sistema lagunar de Alvarado, Veracruz. 8va Reunión científica-tecnologica, forestal y agricola. Veracruz, Veracruz, p. 330–339.
Portilla G., L. E. 1989. Aspectos taxonómicos y ecológicos de los moluscos bentónicos en la laguna de Tamiahua, Veracruz. Bachelor's thesis, UNAM-ENEP-Iztacala, 38 p.
Reguero, M., and A. García-Cubas. 1989. Mollusks of Alvarado, Veracruz: systematics and ecology. An. Inst. Cienc. del Mar y Limnol., Univ. Nac. Autón. México 16(2):279–306.
________ and ________ . 1991. Mollusks of Camaronera, Veracruz: systematics and ecology. An. Inst. Cienc. del Mar y Limnol. Univ. Nac. Autón. México 18(1):1–23.
________ and ________ . 1993. Mollusks of Pueblo Viejo lagoon, Veracruz, México: systematics and ecology. An. Inst. Cienc. del Mar. Limnol., Univ. Nac. Auton, México 20 (1):77–104.
________ , ________ , and G. Zúñiga. 1991. Mollusks of Tampamachoco, Veracruz, México: systematics and ecology. An. Inst Cienc. del Mar y Limnol., Univ. Nac. Autón. México 18(2):289–328.
Rogers, P., and A. Garcia-Cubes. 1981. Gonadic changes at histological level of *Rangia cuneata* (Gray, 1831) in Pom, Campeche, México (Mollusca: Bivalvia). An. Inst. Cienc. del Mar. Limnol., Univ. Nac. Auton. México 8:1–20.
Ruiz, H. E. 1975. Estudio ecologico preliminar de las almejas comerciales del sistema lagunar de Terminos, Campeche, *Rangia cuneata* (Gray, 1831). Bachelor's thesis, Univ. Nac. Auton. México, 80 p.
Segura, C. A. 1980. Estudio Prospectivo de la almeja prieta *Polymesoda carolineana* Bosc. En la Laguna de la Costa. Bachelor's thesis, Univ. Autonoma de Nuevo Leon.
SIIM. 2004. Sistema Nacional de información e Integración de Mercados. Mercado Nacional Pesquero. http://www.economia-sniim.gob.mx/SNIIM-PESCA/edestino1.
Solis-Ramirez, M. J. 1994. Mollusca de la Peninsula de Yucatán. *In* A. Yánez-Arancibia (Editor), Recursos faunisticos del litoral de la Peninsula de Yucatán, p. 13–32. Universidad Autonoma de Campeche. EPOMEX Serie Científica 2.
Stark, B. L. 1977. Prehistoric ecology at Patarata 52, Veracruz, México: Adaptation to the mangrove swamp. Vanderbilt Univ. Publ. in Anthropol. 18, 259 p.
________ . 2001. Classic Period Mixtequilla, Veracruz, México: Diachronic inferences from residential investigations. Inst. Mesoamerican Studies, Monogr. 12, The University at Albany, N.Y., 411 p.
Swingle, H. A., and O. G. Bland. 1974. Distribution of the estuarine clam *Rangia cuneata* Gray in coastal waters of Alabama. Ala. Mar. Resour. Bull. 10:9–16.
Tarver, J. W. 1972. Occurrence, distribution and density of *Rangia cuneata* in Lakes Pontchartrain and Maurepas, Louisiana. La. Wildl. Fish. Comm. Tech. Bull. 1, 8 p.
Tenore, K. R., D. B. Horton, and T. W. Duke. 1968. Effects of bottom substrate on the brackish water bivalve Rangia cuneata. Chesapeake Sci. 9(4):238–248.
Uribe-Martinez, J. A. 1983. Estimación de los daños causados en el recurso almeja en la Laguna del Pom, municipio del Carmen, Campeche, por el tendido de la tuberia de PEMEX, que une cd PEMEX, Tabasco, con las plataformas de explotación. I. N. P.-SEPESCA- Carmen, Campeche, 40 p.

The Steamer *Albatross* and Early Pacific Salmon, *Oncorhynchus* spp., Research in Alaska

PATRICIA ROPPEL

The building in 1882 of the *Albatross* (Allard, 1978, 1988, 1999; Anonymous, 1881; Tanner, 1885, 1897), a deep-sea oceanographic research steamer thoroughly equipped for the purposes of the U.S. Commission of Fish and Fisheries[1], produced the means for U.S. marine science and fisheries studies ranging from coastal shallows to the abyssal depths (Fig. 1, 2). First used on the Atlantic coast, then transferred to the Pacific in 1888, the *Albatross* made annual trips to Alaska for nearly 20 years (Fig. 3)(Dunbar, 1997; Dunbar and Friday, 1994). These trips were interspersed with cruises off California (Moring, 1999), Hawaii (Dunn, 1996b), to more southerly waters of the Pacific (Summers et al., 1996), to the Philippines and Japan (Dunn, 1996b; Smith and Williams, 1999), and to the South Pacific (Agassiz, 1913; Hedgpeth, 1945). Most of the marine surveys were exploratory, with goals of determining the location of fisheries and fishing grounds (Hedgpeth, 1945; Dunn, 1996b, 1996c), though they also produced important ichthyological and oceanographic studies.

Alaska's greatest fish wealth in the 1800's lay in its abundance of Pacific salmon—the five species of *Oncorhynchus* thrived: chinook, *O. tshawytscha*; chum, *O. keta*; sockeye, *O. nerka*; coho, *O. kisutch*; and pink, *O. gorbuscha*. However, the location of harvestable salmon was fairly well-known, and exploration was unnecessary to further encourage those fisheries. Alaska's salmon resources had long since been discovered. Exploitation of Alaska's salmon by non-Native Americans began under Russian rule and advanced quickly after 1867 when Alaska became a U.S. possession. *Albatross* naturalists were not immediately assigned to investigate this already developed and lucrative fishery.

In addition, limited research into the biology of salmon had previously begun (Gard and Bottorff, In press). Systematic research on Alaska's salmon had started in 1879 and 1880 before the *Albatross* arrived on the Pacific Coast. This research was conducted by Tarleton H. Bean[2], who produced the earliest studies of Alaska salmon (Bean, 1887, 1891, 1894).

But Bean was hampered in his studies because most salmon fishing took place in largely unexplored Alaska waters. With no vessel at his disposal, Bean's work was chiefly limited to collecting and studying the fishes obtained along the shores and from the fishermen (Rathbun, 1894).

In addition to his own observations on various species of fish, Bean gathered information about the behavior and harvest of the various salmon species from people who traveled or lived in Alaska such as William Healy Dall[3], U.S. Revenue Service cutter captains, 1880 census-taker Ivan Petroff[4], Alaska Commercial Company employees, and other entrepreneurs. From Bean's visit and compilations came the first publication by the U.S. Commission of Fish and Fisheries concerning Alaska's salmon (Goode et al., 1887).

For a number of years, Bean's work stood as the main reference on Alaska's Pacific salmon. Other examinations were cursory and ancillary to studies of other

[1]Often referred to as the U.S. Fish Commission (USFC) or just the Fish Commission. For general accounts of the Fish Commission see Allard (1978) and Galtsoff (1962).

Patricia Roppel, P.O. Box 1998, Wrangell, AK 99929 (e-mail: patroppel@hotmail.com), is an historian and author. Views or opinions expressed or implied are those of the author and do not necessarily reflect the position of the National Marine Fisheries Service, NOAA, and mention of trade names or commercial firms does not imply endorsement.

ABSTRACT—The U.S. Fish Commission Steamer Albatross *made its first cruise to Alaska in 1888 primarily to research the Pacific cod,* Gadus macrocephalus*; however, Pacific salmon* Oncorhynchus *spp., was also to be studied, if time permitted. In 1889, concern for salmon overharvesting prompted Congress to authorize an investigation into the habits, abundance, and distribution of Alaska's salmon, and in 1890 the* Albatross *returned to Alaska. Over the next 20+ years the* Albatross *made many other productive and pioneering research voyages to Alaska, the last in 1914.*

[2]Bean (1846–1916) served as curator of fishes at the U.S. National Museum [Smithsonian Institution] (1880–1895) and as director of the New York Aquarium (1895–1898). He served as ichthyologist as well as in other capacities for the U.S. Fish Commission during those years.

[3]Dall (1845–1927) served in the U.S. Coast and Geodetic Survey and for the Commissioner of Agriculture before joining the staff at the U.S. National Museum in 1880. He wrote "Alaska and Its Resources" (1870) and numerous technical and scientific papers, many on Alaska topics. Primarily an authority on mollusks, Dall also wrote the official biography "Spencer Fullerton Baird" (1915).

[4]Petroff (b. 1842), author of "Report on the Population, Industries, and Resources of Alaska" (1884), compiled the 1880 census data and wrote a report on Alaska. However, he tended to exaggerate and even fabricate where he could not get adequate information. He apparently did not visit a number of places he easily could have. However, the maps he published in 1880 and 1882 were very accurate.

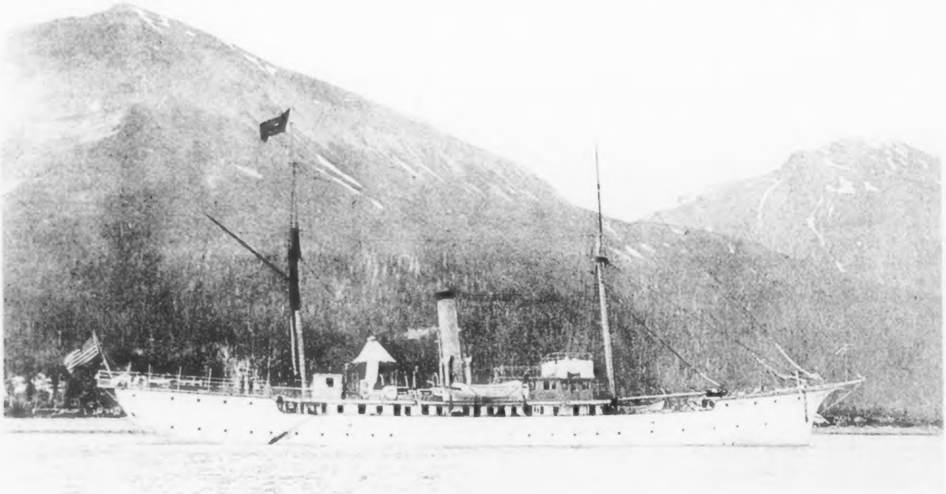
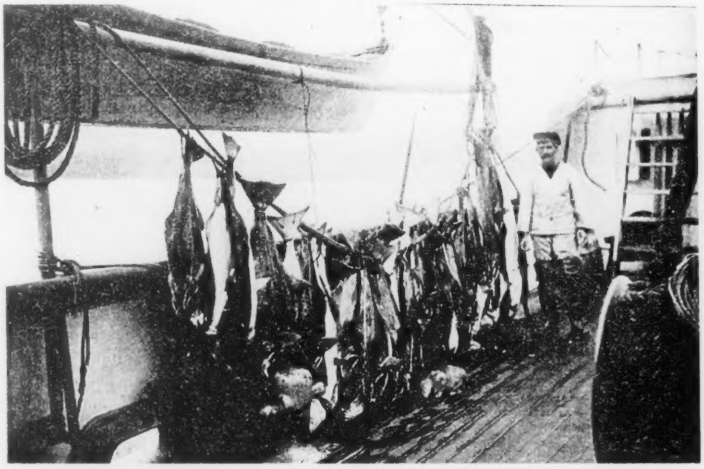


Figure 1.—U.S. Fish Commission Steamer *Albatross* anchored in Resurrection Bay in 1914 (Jones, 1915).

Figure 2.—Coal sacks were stacked in the gangways on the deck of the *Albatross* in 1914. E. Lester Jones wrote "…the Albatross is a coal burner [which] makes her expensive to operate and lessens her efficiency, particularly on account of a reduced steaming radius." (Jones, 1915).



In the 1890's, steamers regularly stopped so excursionists could spend a few hours halibut fishing in Chatham Strait near Killisnoo, southeastern Alaska. In 1898, the men on the *Albatross* fished with 21 handlines in the area and in this photograph display the catch (Moser, 1899).

The Navy crew and naturalists cleaned the halibut caught in the Killisnoo area. In 1.5 h, 143 halibut, average weight 22 lb, were caught. The largest was 165 lb (Moser, 1899).

Figure 3.—Map of Alaska with some of the locations mentioned in the text.

Figure 4—Lieutenant Commander Zera Luther Tanner of the *Albatross*, courtesy of the NOAA Central Library.

Figure 5.—Charles Henry Gilbert, Naturalist-in-Charge on the *Albatross*, ca. 1903, courtesy of Linda Long and the Stanford University Archives.

marine life. This was also true of the first trip of the *Albatross* to Alaska waters.

This cruise took place in 1888 under command of Lieutenant Commander Zera Luther Tanner, USN (Fig. 4).[5] Tanner was ordered to head for Alaska with the focus "…to stimulate fishing interests of the North Pacific Ocean" (Tanner, 1890). The emphasis was on Pacific cod, *Gadus macrocephalus*, and was to determine the extent, character, and resources offshore in the region most used by the American fleet of cod fishermen.

Tanner's instructions regarding salmon stated: "The Alaska fishery was quite fully covered by the fishery census of 1880 and the vessels, boats and fishing gear known at that time are well represented in the fishery collection at the National Museum in Washington. It is desirable, however, to ascertain what changes may have taken place since then; what new styles of boats or gear have been introduced, and to what extent the Natives have adopted the appliances and methods of the white man."[6] Further, his instructions stated that "The fresh waters may also be examined, should the time permit, with special reference to salmon…."[6,7] Tanner's scientific staff included Charles H. Gilbert, Naturalist-in-Charge[8] (Fig. 5), and his assistants Leslie A. Lee, Charles H. Townsend, and A. B. Alexander.

In final reports for the 1888 cruise, there are very few descriptions of salmon. The *Albatross* stopped occasionally at places where salmon were being taken and processed. At Ivan Pavloff's saltery 15 miles from Coal Bay, Alexander learned that Pavloff had been fishing for 3 weeks. Eighteen white men and a few Native Americans caught enough

[5]Lieutenant Commander Zera Luther Tanner (1835–1906) commanded the *Albatross* from its construction in 1882 until 1894.

[6]Tanner, Z. L., "*Albatross* Report, San Francisco to Alaska and Aleutian Islands, 1888," Record Group (RG) 22, Records of the U.S. Fish and Wildlife Service, Entry (E) 63, General, Records of the U.S. Fish Commission and Bureau of Fisheries. National Archives, Silver Spring, Md., NA.

[7]The "fishery census of 1880" was an exceptionally large and thorough review of all U.S. fisheries made in concert with the U.S. census that year. It was published in six large volumes (Goode et al., 1887).

[8]As Naturalist-in-Charge, Gilbert (Dunn, 1996a) was likely an "independent" scientist and not part of Tanner's command. Pietsch and Anderson (1997) provide more information on some of the scientists mentioned in this paper.

salmon for 400 barrels from a small lake where salmon came in incredible numbers to spawn.[9]

Tanner described a visit to a fishing station built in 1887 at Humboldt Harbor in the Shumagin Islands. Here he questioned local people about salmon run timing, but he included no details in his report. He also described the process used by the Aleuts to catch and dry salmon at Unalaska Bay.[6]

While anchored in Unalaska Bay, the *Albatross* crew seined half a boat load of pink salmon or "humpies" and chum salmon. The crew salted two-thirds of a barrel for use to replace clams as bait for the cod trawl lines.[6]

The following year, 1889, the *Albatross* and its naturalists did not intend to return to Alaska. Still under the command of Tanner, the *Albatross* was assigned to investigations off the shores of Washington and Oregon. However, she was interrupted for a trip to Alaska by the Bureau of Indian Affairs for ethnological surveys.

Four members of the Senate Committee on Indian Affairs, headed by Senator Henry L. Dawes (R., Mass.), boarded the ship to sail to Alaska to inspect the principal Indian settlements. The vessel stopped at Fort Tongass, Port Chester (later known as Metlakatla), Karta Bay, Fort Wrangell, Sitka, Pavloff Harbor, Hoonah Bay, Portage Bay, Chilkat, and Juneau. A number of these places were sites of significant salmon fisheries and canneries or salteries.

What did the scientific staff of Gilbert, Townsend, and Alexander do during these 3 weeks? Local newspapers interviewed the Senators whom they undoubtedly found more prestigious than the naturalists (The Alaskan, 1889). Subsequent official reports from the U.S. Fish Commission include only the statement that "Several important fishing stations and canneries were visited, and some investigations were also made by means of the beam trawl and other kinds of fishing apparatus" (Rathbun, 1894).

It was about this time, the end of the 1880's, that a mission for salmon research in Alaska developed: conservation of the resource. Overharvest, by any means and method, was the norm, especially in the very productive Kodiak–Karluk region. Many cannery owners from Washington, Oregon, and California had headed north to Alaska, and by 1888, Alaska streams furnished much of America's canned Pacific salmon. Concerns that the salmon runs could not continue with such pressure were intensified by destruction of salmon on the Sacramento River and reduction of the harvests on the Columbia River (Bean, 1891).

How could conservation be effective if no one knew the current extent of the resource? Government officials agreed that more knowledge of Alaska's salmon resources was necessary before regulations could be promulgated.

The first Federal legislation involving Alaska's salmon fisheries was an attempt to rectify this lack of knowledge. Congress in 1889 authorized an investigation into the habits, abundance, and distribution of Alaska's salmon. This also included an examination of the conditions and methods of the fisheries.

Even in those days, scientists and government officials discussed the role of conservation in offsetting the dangers to supply that are inherent in technological advances. But in reality, the only regulatory inclusion in this first legislation outlawed the obstruction of a salmon stream by artificial means (Roppel, 1982). This concern about Alaska's salmon fisheries looked good on paper, but Congress failed to appropriate the funds needed to cover the expenses of such an investigation or to enforce the law on stream barricades.

Bean took matters in his own hands and arranged to take money from the U.S. Fish Commission's general appropriation for fish propagation and use it to place a team of investigators in the field. He chose Livingston Stone[10], superintendent of salmon hatcheries in California and Oregon, and Franklin Booth, of the University of California, to study topographical and physical features of different river basins of Alaska (Bean, 1891).

The geographical dimensions of the Alaska salmon fisheries are overwhelming. They extend over 2,000 miles along the entire coast from southeastern Alaska to the Bering Sea. Bean's instructions from U.S. Fish Commissioner Marshall McDonald were to limit work to Kodiak and Afognak Islands, Cook Inlet, and Bristol Bay (Bean, 1891).

At that time, the *Albatross* was engaged in fishery and deep-sea investigations off lower California, and Bean and his party apparently had no access to the vessel. Perhaps Commissioner McDonald continued his philosophy expressed during the first cod survey in 1888. At that time he said "...this branch of [salmon] inquiry, however, can be as well undertaken by a party moving by ordinary conveyance from Sitka or San Francisco...."[6]

But by the end of the season of 1889, Bean wrote in his transmittal letter for his final report: "There is practically no communication in Alaska except by water. There are no lines of vessels running regularly from place to place, and whenever it is desirable to cover an extended field of investigation it is essential to provide a vessel to carry the party to the places to be investigated" (Bean, 1891).

Bean's final report gives an understanding of why he made this plea. His investigative party left San Francisco on a Karluk Packing Company steamer that proceeded directly to the cannery headquarters on the Karluk River. From there, the men relied on the canning companies for transportation and hospitality. As a consequence, the investigations were limited to Kodiak and Afognak Islands, although two Cook Inlet canneries were apparently visited. This left the fisheries of Bristol Bay, Prince William Sound, and southeastern Alaska unexplored.

The scientists studied physical characteristics of the environment and of salmon; natural history; methods, conditions, and statistics of the fisheries; and the possibilities of artificial propagation of salmon in Alaska. Stone expressed the

[9]Alexander, A. B., "Narrative of the voyage of the Steamer *Albatross*, 1888," RG 22, E 91, NA.

[10]Livingston Stone, a New Hampshire fish culturist, established the first USFC fish hatchery on the Pacific Coast in 1872 on California's McCloud River and investigated other potential West Coast fish culture sites for the Fish Commission.

opinion that such propagation posed no difficulties (Bean, 1891) .

After Bean's survey, salmon again became an adjunct to other investigations. In 1890, the *Albatross*, with Tanner still in command and Charles H. Gilbert as chief naturalist, returned to the Alaska waters of Bristol Bay and the waters near the Aleutian Islands. Again, the cod banks were sought out.

During that season, the ship stopped at the Naknek River, considered the head of deep-water navigation in Bristol Bay (Fig. 6). With any normal-draft ocean vessel, such as the *Albatross*, it was difficult to explore the Bristol Bay fisheries because of the shallow waters at the mouths of the rivers.

Before leaving for Alaska, Tanner had been instructed by the U.S. Fish Commissioner Marshall McDonald to stop at the Nushagak River to see if the cannerymen were building a trap or dam completely across the Wood River, a tributary of the Nushagak River (Fig. 7).[11] The *Albatross* anchored near the mouth of the river and, while Alexander went upriver in a small boat, triangulation and astronomical observations were made. Alexander collected information on the four salmon canneries, recording the number of men and boats, the method of fishing adopted by all the canneries, the timing of the salmon runs, and fish size at time of harvest (Tanner, 1891). He found no traps in place and was told traps were not sufficiently effective to offset the cost of maintaining them in the swift river. Since Alexander was at the mercy of the cannerymen for his information, it is possible that traps may have been removed for his visit.

After exploration of the cod grounds, the *Albatross* scientists turned their attentions to northern fur seals, *Callorhinus ursinus*. The Bering Sea was the focus of international attention on the exploitation and threat of extermination of this marine mammal. The *Albatross* was also used in connection with Naval patrols during the Bering Sea controversy over fur seal issues.[12]

Figure 6.—Arctic Packing Company cannery on the Naknek River. The small, double-ended dorries were used by fishermen who rowed or sailed to the fishing grounds because motorized vessels were prohibited. Steamers carried supplies between Bristol Bay's rivers and, at the end of the season, carried the canned salmon south (Moser, 1902).

Figure 7.—Salmon trap on the Nushagak River (Moser, 1902).

For some of this period, 1891–94, the original reports of the *Albatross* commander are missing from the National Archives records, so it is unknown if any mention of salmon is included. However, in 1895, the *Albatross* captain, Lieutenant Commander F. J. Drake, USN, was instructed that the naturalists should not neglect to check fisheries in relation to the fur seals.[13]

The subsequent report contains much the same references to salmon as those in

[11] Marshall McDonald to Z. L. Tanner, April 23, 1890. File "*Albatross*, Correspondence Covering Seal, Sea Otters, and Fisheries 1890–1895." RG 22, E 91, Division of Alaska Fisheries Correspondence, Reports and Other Records, NA.

[12] In 1881 the price of fur seal pelts trebled, and seal hunters began pelagic sealing—taking of the animals at sea. Females, as well as males, were taken, and many seals sank after being killed, causing fears that the seals would be hunted to extinction. The United States considered the Bering Sea its waters. The *Corwin*, a U.S. Revenue Cutter Service vessel, seized one American ship and three Canadian ships for illegal sealing activities and precipitated the long controversy between the United States and Great Britain that nearly led to armed conflict between the two nations. Eventually, in July 1911, Japan, Great Britain, Russia, and the United States passed a treaty concerning the seals (Strobridge and Noble, 1999).

[13] "Instructions to *Albatross*, April 22, 1895" and "Notes concerning Fur Seal Investigations, 1893–94", RG 22, E 91, NA.

1888. At a village in Ikatan Bay, fishing, hunting, and seining parties were sent out. Flounders (Pleuronectidae), sculpins (Cottidae), small Pacific cod, young and large Pacific salmon, salmon trout (possibly *O. mykiss*), "sea trout" or cutthroat trout, *O. clarkii*; and various species of clams were found.[14]

In keeping with instructions to report on Native fishing methods, Alexander wrote: "On certain week days during the salmon season, the seine was hauled by Native women who waded into the water up to their shoulders while the men stood on the shore and directed their movements. The work is looked upon by the former as a privilege rather than a hardship. If a Native woman should allow her husband to perform this work for her, he would be looked down upon by all the other women of the village. The so-called privilege has been in vogue so long that it would be hard to change the custom."[14] Intensive salmon research was not yet a high priority.

Fishing in Alaska, however, had boomed since Bean's first report when 16 canneries packed about a half million cases (Bean, 1887). By 1896, 29 canneries packed nearly one million cases (Tingle, 1897). New canneries and salteries sprang up yearly (Freeburn, 1976).

Because of this dramatic increase over a decade, conservation again surfaced as a pressing mission for the U.S. Fish Commission. For years, U.S. Treasury agents had emphasized the need for regulating the harvest. In 1892, the Treasury Department, the regulatory agency for Alaska's fisheries, had appointed an agent and an assistant to gather fishery statistics and publish them in an annual report. Both agencies were also to enforce the laws, which were limited and inadequate.

Thus, in 1897, Alaska salmon research finally came to the forefront. The *Albatross*, under the command of Lieutenant Commander Jefferson Moser, USN,[15] played an integral part in the investigations.

Figure 8.—This view of Yakutat's cannery in 1914 is typical of the illustrations in the reports of Moser and Jones. Often these U.S. Fish Commission photographs are the only historical record of what these canneries looked like (Jones, 1915).

The object of the renewed investigations was to determine the conditions of salmon in the different and widespread regions of Alaska. This was again thought to be necessary so that suitable laws for the protection of the fishery might be framed (Moser, 1899). The U.S. Fish Commission developed a plan of work to provide data to manage the different stocks in the diverse areas of Alaska. This outline became the basis for the investigation of the Alaska salmon streams and its industry for many years.

Since fishermen concentrated on sockeye salmon, *O. nerka*, which dominated the canned pack, Moser's party was instructed to explore and study sockeye streams and lakes including spawning grounds, nature of the water, characteristics of the vegetation, species of salmon entering streams, their movements, timing, and length of run; size of fish, signs and causes of depletion, natural and artificial obstructions, and fishing methods and their relationship to the maintenance of supply. In addition, statistics were to be collected from the canneries about streams fished and the catch from each (Moser, 1899).

Moser's staff consisted of U.S. Navy officers except for A. B. Alexander, H. C. Fassett, and F. M. Chamberlain (Moser, 1899). Lieutenant L. M. Garrett, executive officer of the *Albatross*, took observations for geographical positions. H. E. Parmenter, in addition to his duties as chief engineer, conducted the field work for nearly all the surveys, and he plotted the work. Lieutenant J. P. McGuinness conducted the field work of several surveys but was mostly engaged in examining salmon streams and lakes. Ensigns Yakes Stirling, Jr., and S. V. Graham assisted Parmenter and Alexander. Stirling conducted the hydrographic work. Chamberlain and Fassett assisted, and both took glass-plate photographs (Fig. 8).[16]

Thus, began a systematic examination of the salmon streams of Alaska, the likes of which had never been done before. The *Albatross* became the base of operations, and the men used a steam cutter, a steam gig, and rowboats in shallow waters.[17]

From Moser's explorations came "Alaska Salmon and Salmon Industries" (Moser, 1899), an authoritative work published by the U.S. Commission of Fish and Fisheries. In one short season, his Naval officers and the three naturalists had produced a prodigious amount of information about Alaska's salmon, especially in southeastern Alaska.

One season, however, was not enough to finish a salmon survey of all Alaska.

[14] Drake, F. J., General report of the movements and operations of the U.S. Fish Commission Steamer *Albatross* for the first half of the fiscal year of 1895, RG 22, E 91, NA.

[15] Moser (1848–1934), a U.S. Naval Academy graduate, was attached to the Hydrographic Division of the U.S. Coast and Geodetic Survey before taking command of the *Albatross*. He captained the ship for nearly 6 years. He retired as a Rear Admiral in 1904 and then became vice-president and general manager for Alaska Packers Association.

[16] The extensive collection of photographic prints taken by Chamberlain and Fassett are available at the National Archives, Still Picture Branch, Record Group (RG) 22.1.

[17] Moser, Jefferson F., "Report of U.S. Fish Commission Steamer *Albatross* from 1st July 1897 to 31st December 1897, Part 1." RG 22, E 63, NA.

Bering Sea district:
- Left Unalaska July 3.
- Bristol Bay, July 5–19.
- Unalaska, July 21–24.

Kadiak and Chignik district:
- Chignik Bay, July 28–29.
- Alitak Bay, July 30–August 7.
- Karluk, August 7–9.
- Uyak, August 9–11.
- Afognak, August 11–16.

Southeast Alaska district:
- Sitka, August 19–21.
- Killisnoo, August 21–22.
- Pyramid Harbor, August 22–23.
- Chilkoot Inlet, August 23–25.
- Taku Inlet, August 25–26.
- Taku Harbor, August 26–27.
- Port Snettisham, August 27.
- South Bay of Pillars, August 28–September 2.
- Shipley Bay, September 2–4.

Southeast Alaska district—Continued.
- Duncan Canal, September 5–8.
- Point Highfield, September 8–10.
- McHenry Inlet, September 10–12.
- Zimovia Strait, September 12–13.
- Union Bay, September 13–14.
- Ward Cove, September 14–15.
- Loring, September 15–17.
- Yes Bay, September 17–21.
- Karta Bay, September 21–23.
- Loring, September 23–24.
- Ketchikan, September 24.
- Boca de Quadra, September 24–25.
- Metlakahtla, September 25–27.
- Comox, British Columbia, October 2–3.
- Tacoma, Washington, October 4–17.
- Quartermaster Harbor, Washington, October 17–21.
- Comox, British Columbia, October 24–26.
- Sausalito, Cal., October 30.

Figure 9.—The *Albatross* cruise itinerary, summer 1900 (Moser, 1902).

Moser wrote to the Commissioner of Fisheries saying, in part, "...in my opinion there is no work on the coast upon which the *Albatross* could be employed that will bring a better return of the money expended. The seal question is a small one compared to the salmon interests of the country and unless the authorities take proper steps to enforce the law, the time is not far distant when the canneries will gradually have to be abandoned."[18] But Moser's opinion was ignored, and he and the *Albatross* were soon headed to the South Pacific for 2 years on a charter to study its sea life.[19]

The *Albatross*, still under Moser's command, returned to Alaska for the season of 1900 and arrived in Unalaska on 29 June. Due to the rush to the gold fields at Cape Nome, the ship had to wait her turn to load coal and didn't get underway until the evening of 3 July (Fig. 9, 10). Moser's work continued during the following season of 1901 (Fig. 11). His staff in both years again consisted of Naval officers augmented by Fassett and Chamberlain.

Figure 10.—As a coal burner, the *Albatross*, to extend her range, carried a load of sacked and loose coal on the foreward deck (Jones, 1915).

Most of the three seasons were spent in southeastern Alaska where there is a preponderance of sockeye salmon streams. In addition, Moser visited several previously unsurveyed regions to document salmon resources. His visit to the Alsek River and Yakutat Bay was the most comprehensive fisheries exploration of that area (Moser, 1902).

[18] Moser, Jefferson F., to Commissioner of Fisheries, dated 4 September 1897, "*Albatross*, Correspondence and Reports, 1897,"RG 22, E 63, NA.

[19] Alexander Agassiz's first two research expeditions on the *Albatross* were in 1891 (Panama–Galapagos region) and during 1899–1900, his longest expedition, through the South Seas islands and ending in Yokohama, Japan.

Southeast Alaska:		*Southeast Alaska*—Continued.	
Hunter Bay, Prince of Wales Island	May 29–31.	Kook (Basket) Bay, Chichagof Island	June 19.
Niblack Anchorage, Prince of Wales Island	May 31–June 1.	Pablof Harbor, Freshwater Bay	June 19–21.
Moira Sound, Prince of Wales Island	June 1.	Juneau	June 21–24.
Tamgas Harbor, Annette Island	June 1–3.	Hunter Bay, Admiralty Island	June 24–25.
Metlakahtla, Annette Island	June 3.	Bartlett Bay, Icy Strait	June 25–27.
Ketchikan, Tongass Narrows, Revillagigedo Island	June 3–5.	Dundas Bay, Icy Strait	June 27–29.
George Inlet, Revillagigedo Island	June 5.	Yakutat	June 30–July 7.
Mary Island Anchorage	June 5–6.	*Prince William Sound:*	
Kah-Shakes Cove, entrance to Boca de Quadra	June 6.	Orca	July 8–10.
Smeaton Bay, Behm Canal	June 6–7.	Port Gravina	July 10–11.
Checats Cove, Behm Canal	June 7.	Naked Island Anchorage	July 11.
Yes Bay, Cleveland Peninsula	June 7–8.	Herring Bay, Knight Island	July 11–15.
Loring, Naha Bay	June 8–10.	Naked Island Anchorage	July 15–18.
Ketchikan, Tongass Narrows, Revillagigedo Island	June 10.	Port Valdez	July 18–21.
Steamer Bay, Etolin Island	June 10–11.	*Southeast Alaska:*	
Kunk Creek, Etolin Island	June 11.	Sitka	July 23–25.
Wrangell, Wrangell Island	June 11–13.	Nakwashina Bay, Baranof Island	July 25–Aug. 3.
Salmon Bay, Prince of Wales Island	June 13.	Schultze Cove, Baranof Island	Aug. 3–4.
Conclusion Island (off Kuiu Island)	June 13–14.	Hanus Bay, Baranof Island	Aug. 4–5.
Point Barrie, Kupreanof Island	June 14.	Sitkoh Bay, Chichagof Island	Aug. 5–6.
Port Protection, Prince of Wales Island	June 14–15.	Hoggatt Bay, Baranof Island	Aug. 6–7.
Shakan Bay, Kosciusko Island	June 15–17.	Baht Harbor, Zarembo Island	Aug. 7–8.
Kell Bay, Kuiu Island	June 17–18.	Steamer Bay, Etolin Island	Aug. 8–11.
Killisnoo Harbor, Kenasnow Island	June 18–19.	Ward Cove, Tongass Narrows, Revillagigedo Island	Aug. 11–12.
		Washington:	
		Port Discovery, Quarantine Station	Aug. 17.

Figure 11.—The *Albatross* cruise itinerary, summer 1901 (Moser, 1902).

During the summer of 1900, the *Albatross* party conducted the first comprehensive on-site examination of all of Bristol Bay's salmon fisheries. Up to that point, even the Treasury Department's agents had difficulty reaching this remote area. Most of the information the U.S. Fish Commission had about Bristol Bay, except that sent by salmon packers, came from Alexander's 1890 notes and Moser's 1897 report, with the latter coming from second-hand sources. In 1897, 28% of Alaska's pack came from Bristol Bay, 90% of that by the Alaska Packers Association, from whom Moser had collected his information.[20]

Exploration from the *Albatross* in 1900 into the vast unexplored interior was limited because of the size and length of the rivers, some of which were not explored to their headwaters until 1908. However, as much information as possible was collected including interviews with local Natives and the salmon packers.

The salmon streams and canneries of Prince William Sound had been neglected and were unsurveyed prior to the *Albatross*' and Moser's arrival. "It is very difficult, in absence of charts and maps, to describe the fisheries of this section," he wrote in 1897 (Moser, 1899). In 1900 his information was second-hand, so in 1901, the Naval officers did the usual work-up on several streams and then collected cannery data (Fig. 12). However, this survey was more hit and miss than in other salmon regions (Moser, 1902).

Despite the new information available to the U.S. Fish Commission for use in drafting legislation to regulate Alaska's fisheries, it appears that little use was made of it. The prohibition against the use of barricades in streams, enacted in 1889, continued to be more or less enforced depending upon where the two Treasury agents happened to be in Alaska. An act passed in 1896 prohibited fishing in the mouths of several salmon streams. The first time limitation on fishing was also introduced that year. Again, enforcement was hampered by the limited ability of the Treasury agents to patrol Alaska when they had no vessel dedicated to their use.

After the first season of Moser's work, the first legislation regarding Alaska's salmon came in 1900 when cannery owners were required to establish sockeye hatcheries (Roppel, 1982). In 1902, further regulations limited traps to covering no more than one-third of the stream mouth, defined prohibition of seining and gillnetting in mouths of streams, and prohibited wanton waste of salmon (Alaska Fish Commission, 1904).

A further study of Alaska's salmon was sought 2 years after Moser completed his work. At the request of President Theodore Roosevelt, an Alaska Fish Commission was appointed early in 1903

[20]Moser, Jefferson F., "Report of operations *Albatross* from 1st July 1897 to 31st December 1897, Part 3." RG 22, E 63, NA.

to "submit a report embodying results of investigations covering all matters of importance in connection with salmon and capture, and deal fully with regulation and administration of fisheries" (Alaska Fish Commission, 1904). This took place just months before the 1 July 1903 transfer of responsibility for Alaska's fisheries from the Treasury Department to the newly created Department of Commerce and Labor, Bureau of Fisheries.[21]

The *Albatross*, under command of Lieutenant Franklin Swift, USN, was assigned to support the Alaska Fish Commission party. This time, however, the research was under the control of naturalists and ichthyologists rather than Naval officers. This new study was headed by David Starr Jordan, noted ichthyologist and President of Stanford University, then known as Leland Stanford Junior University (Alaska Salmon Commission, 1904). Barton Warren Evermann took over during the latter part of the investigation when Jordan was absent. The party also included Charles H. Gilbert, assigned to study the fisheries of Bristol Bay while stationed at Nushagak; Harold Bowen Jordan, also of Stanford University, in charge of shore fishing and seining operations; Alexander, to gather data on run timing[22]; and Fassett, to gather data on methods used in the canneries and salteries. Chamberlain and his assistant were assigned shore studies at Loring in southeastern Alaska.[23] Albertus Baldwin was commissioned to paint illustrations of the five species of salmon. Cloudsley Rutter, naturalist for the *Albatross*, and an assistant were sent to the Karluk River on Kodiak Island to study the salmon at that much-fished site. J. Nelson Wisner would examine the compulsory hatcheries built in compliance with the 1900 act.[24]

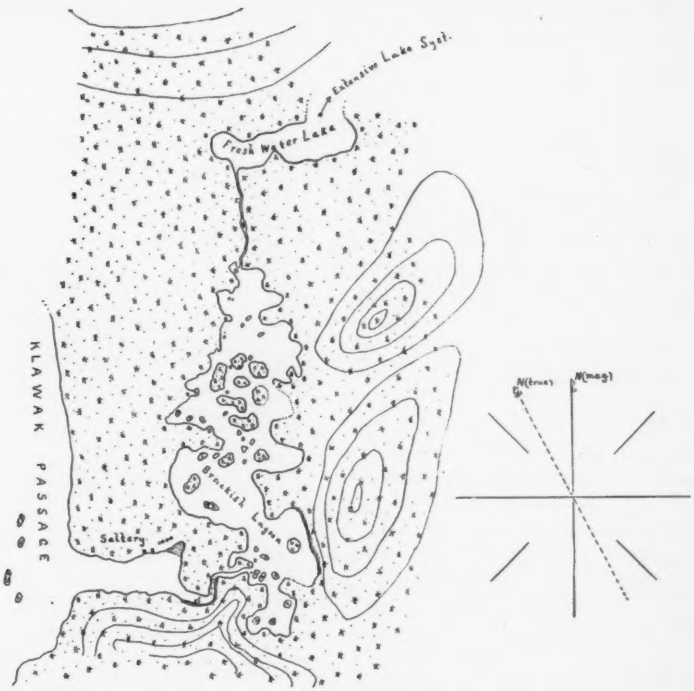


Figure 12.—The U.S. Navy officers sketched the terrain and outline of Alaska's major sockeye systems. This sample of the Sarkar (correct spelling today) system shows what extensive explorations were undertaken, sometimes far inland, on geographic areas heretofore unrecorded (Moser, 1902).

The work plan for the Alaska Fish Commission is 52 pages long, 15 pages longer than the preliminary report that was published after the trip.[25] It not only outlined job descriptions for each of the scientists, but it outlined dredging, collecting, and hydrographic operations at specific locations in southern southeastern Alaska and Kodiak Island waters. Statistics for publication in Moser's format were to be collected. The waters of Bristol Bay, Loring, San Alberto Bay, Klawock Lake, and Klawock River were to be included.[26] However, not all sites mentioned could be visited in one year.

The preliminary report, subtitled "Report Dealing with Legislative Protection of Fisheries," was transmitted to President Theodore Roosevelt under Jordan's and Evermann's names. There was a strong push to abandon the mandatory hatchery legislation and place sockeye hatchery operation in the hands of the government (Alaska Fish Commission, 1904).

This was not unexpected, as the idea of putting fish propagation in the hands of the users had long been questioned. Alaska's Governor John G. Brady stated in his annual report that "There seems to be a consensus of opinion that the government should take the salmon

[21] Originally an independent agency, the U.S. Fish Commission was renamed the U.S. Bureau of Fisheries in 1903 and placed in the new Department of Commerce and Labor.

[22] Alvin B. Alexander was assistant in charge of statistics and methods of fisheries in the U.S. Bureau of Fisheries in 1903.

[23] Loring was the site of an Alaska Packers Association (APA) cannery. A system of lakes feeding the Naha River supports a large sockeye population. APA operated a private hatchery on Heckman Lake, one of the lakes.

[24] Wisner was the field superintendent of the Federal fish culture stations in Alaska in 1903.

[25] "*Albatross* Correspondence concerning Dr. Gilbert's Work, 1888–1902," RG 22, E 91, NA.

[26] Loring, on Revillagigedo Island, was near the Alaska Packers Association's mandatory sockeye salmon hatchery. San Alberto Bay is a body of water between Prince of Wales and San Fernando Islands and constitutes the outside waters through which sockeye salmon pass to Klawock Lake and Klawock River. The latter two are on Prince of Wales Island, and a mandatory sockeye hatchery operated on the lake at that time.

hatcheries in hand and be alone responsible for stocking the streams and keeping the salmon culture up to its highest efficiency and that the canneries should be taxed for the support of the work in proportion to the pack of each" (Brady, 1903).

As for regulations, the Alaska Fish Commission recommended putting the inspection of salmon fisheries and all other matters pertaining to Alaska fisheries in the hands of trained men under control of the U.S. Bureau of Fisheries. Jordan and Evermann considered the research of other investigators, including Moser, and in the preliminary report produced synopses of species, rivers, methods used in the fisheries, packers, and the 1902 salmon pack that had risen to 2.6 million cases by that time.

Further reports were forthcoming over the next few years after the scientists/naturalists had time to examine the data collected. Chamberlain extended his stay at Loring for another season (1904) and then spent the summer of 1905 at Yes Bay at the Bureau of Fisheries hatchery.[27] From this field work, Chamberlain analyzed his observations of young salmon, the specimens collected aboard the *Albatross* throughout Alaska, along with some of Moser's data from southern southeastern Alaska and information from the Karluk system obtained by Rutter.[28] Chamberlain's report discussed the known facts about the life of adult salmon, including the spawning period, detailed descriptions of adult and young salmon, and sea habits of young salmon from various places including the northern Pacific Ocean and Bering Sea (Chamberlain, 1907).

Evermann, with coauthor Edmund Lee Goldsborough, incorporated much of the data collected in 1903 in their publication "The Fishes of Alaska" (Evermann and Goldsborough, 1907). All Alaska specimens at the U.S. National Museum (Smithsonian Institution), many of which were collected during *Albatross* voyages, were examined. This publication put on record the important information concerning the habits, abundance, and distribution of salmon and discussed some of the chief problems connected with the salmon fisheries.

Figure 13.—The U.S. Bureau of Fisheries Steamer *Osprey* at Zarembo Island in 1914 (Jones, 1915).

One last trip was made by the *Albatross* in conjunction with Alaska's salmon research. Perhaps this too was prompted by yet another change in the umbrella agency for Alaska's fisheries. In 1913, the Department of Commerce and Labor was divided, and the Bureau of Fisheries stayed in the Department of Commerce. In 1914, William C. Redfield, the Secretary of Commerce, sent Deputy Commissioner of Fisheries E. Lester Jones to Alaska to make a thorough survey and investigation of the various fisheries industries and the fur seal operations. That summer, using the *Albatross*, commanded by Lieutenant L. B. Porterfield, USN, Jones visited canneries, mild-curing establishments, and salteries, as well as the fur seal operations in central and western Alaska.

When it came time to visit the processing plants in southeastern Alaska, Jones and his assistant transferred to another Bureau of Fisheries vessel, the *Osprey* (Fig. 13). After traveling aboard the *Albatross*, Jones was not impressed with the 72-foot *Osprey* calling her "unseaworthy, top heavy, and quite unsuited to the needs of the service" (Jones, 1915). However, the local fisheries agents finally had access to their own mode of transportation and were no longer dependent upon commercial transports or those of the salmon processors.

Commissioner Marshall McDonald's theory that salmon fisheries could be studied without the use of a vessel dedicated to that purpose was again proven wrong. Jones stated, "Without the *Albatross* this past season, the result of my trip would have been anything but satisfactory" (Jones, 1915).

After his investigations, Jones abandoned the publication format used by his predecessors, and his report is superficial in comparison. Much time was spent on the methods of catching salmon, and Jones wrote, "There is probably no part of this great industry that has created more controversy than the methods employed in catching the 60 million fish which are taken each year from the waters of Alaska" (Jones, 1915).

The *Albatross*, with its complement of scientists aboard, did not return to Alaska again to study salmon or any of the region's other fishery resources. Approaching the end of its long and immensely productive marine science

[27]Yes Bay was the site of a cannery which started as a saltery in 1886. McDonald Lake, nearby, produces large runs of sockeye salmon. The U.S. Bureau of Fisheries built a hatchery at the head of the lake in 1906.

[28]Cloudsley Rutter died in 1903 before working up his data.

career, the *Albatross* served on U.S. Navy patrol duty in the Caribbean Sea in World War I and was eventually retired from Federal service in 1921.

Today intelligent biological management of salmon populations continues to be a complex and diverse problem. Solid biological groundwork for the regulation of the Alaska salmon fishery continues. However, much of the base-line data about Alaska's salmon came from the meticulous early work of scientists aboard the *Albatross*.

Literature Cited

Agassiz, G. R. 1913. Letters and recollections of Alexander Agassiz with a sketch of his life and work. Houghton Mifflin Co., The Riverside Press, Cambridge, Mass., 454 p.

Alaska Salmon Commission. 1904. Preliminary report of the Alaska Salmon Commission. 58th Cong. 2d Sess. House of Representatives, Doc. 477. Gov. Print. Off., Wash., 37 p.

Allard, D. C., Jr. 1978. Spencer Fullerton Baird and the U.S. Fish Commission. Arno Press, N.Y., 424 p.

__________. 1988. Spencer Fullerton Baird and the foundations of American marine science. Mar. Fish. Rev. 50(4):124–129.

__________. 1999. The origins and early history of the Steamer *Albatross*, 1880–1887. Mar. Fish. Rev. 61(4):1–21.

Anonymous [Z. L. Tanner]. 1881. Specifications for building the screw-steamer *Albatross*. U.S. Light-House Establishment, Wash., 51 p.

Anonymous. 1889. [News article.] The Alaskan, Sitka, 20 Aug.

Bean, T. H. 1887. The fishery resources and fishing-grounds of Alaska. 47th Congress, 1st Sess., Misc. Doc. 124, Part III. Gov. Print. Off., Wash., p. 81–114.

________. 1891. Report on the salmon and salmon rivers of Alaska, with notes on the conditions, methods, and needs of the salmon fisheries. Bull. U.S. Fish Comm. Vol. IX for 1889, Wash., p. 165–208.

________. 1894. Bibliography of the Salmonidae of Alaska and adjacent regions. Bull. U.S. Fish Comm. Vol. XII for 1892, Wash., p. 39–49.

Brady, J. G. 1903. Report of the Governor of the District of Alaska to the Secretary of the Interior for 1903. Gov. Print. Off., Wash., 21 p.

Chamberlain, F. M. 1907. Some observations on salmon and trout in Alaska. *In* Rep. Comm. Fish Fish. FY 1906 and Spec. Pap., Bur. Fish. Doc. 627, 112 p.

Dall, W. H. 1870. Alaska and its resources. Lee and Shephard, Boston, 627 p.

__________. 1915. Spencer Fullerton Baird, a biography. J. B. Lippincott Co., Phila., 462 p.

Dunbar, K. 1997. In the hands of the federal government: The research steamer *Albatross* and environmental crisis in Alaska. M.A. Thesis, West. Washington Univ., iii + 103 p.

__________ and C. Friday. 1994. Salmon, seals, and science: The *Albatross* and conservation in Alaska, 1888–1914. J. West. 33(4):6–13.

Dunn, J. R. 1996a. Charles Henry Gilbert, pioneer ichthyologist and fishery biologist. Mar. Fish. Rev. 58(1–2):1–2.

__________. 1996b. Charles Henry Gilbert (1859–1928), Naturalist-in-Charge, and Chauncey Thomas, Jr. (1850–1919), commanding: conflict aboard the U.S. Fish Commission Steamer *Albatross* in 1902. Mar. Fish. Rev. 58(1–2):3–16.

__________. 1996c. Charles Henry Gilbert (1859–1928), Naturalist-in-Charge: the 1906 North Pacific Expedition of the Steamer *Albatross*. Mar. Fish. Rev. 58(1–2):17–28.

Evermann, B. W., and E. L. Goldsborough. 1907. The fishes of Alaska. U.S. Bur. Fish. Doc. 62, 360 p.

Freeburn, L. 1976. The silver years of the Alaska canned salmon industry: an album of historical photos. Alaska Geogr. 3(4):1–168.

Galtsoff, P. S. 1962. The story of the Bureau of Commercial Fisheries Biological Laboratory, Woods Hole, Massachusetts. U.S. Dep. Inter., Bur. Commer. Fish., Circ. 145, 121 p.

Gard, R., and R. L. Bottorff. In press. Karluk Lake and River, Kodiak Island, Alaska: A history of sockeye salmon research 1889–1998. U.S. Dep. Commer., NOAA Tech Memo. NMFS-F/SPO.

Goode, G. B., and a Staff of Associates. 1887. The fisheries and fishery industries of the United States. Sec. I–V. U.S. Comm. Fish Fish., Wash., 6 vol., var. pagin.

Hedgpeth, J. W. 1945. The United States Fish Commission Steamer *Albatross*. Am. Neptune 5(1):5–26.

Jones, E. L. 1915. Report of Alaska investigations in 1914. U.S. Bur. Fish., Wash., 155 p.

Moring, J. R. 1999. Cruises of the *Albatross* off San Diego and other parts of southern California. Mar. Fish. Rev. 61(4):22–30.

Moser, J. F. 1899. The salmon and salmon fisheries of Alaska. U.S. Comm. Fish Fish., Wash., 178 p.

__________. 1902. Alaska salmon investigations in 1900 and 1901. Bull. U.S. Fish Comm. Vol. XXI for 1901, Wash., 398 p.

Petrof, I. 1884. Report on the population, industries, and resources of Alaska. Repr. from U.S. Census Rep., 10th Census, 1880, Wash., 189 p.

Pietsch, T. W., and W. D. Anderson, Jr. (Editors). 1997. Collection building in ichthyology and herpetology. Am. Soc. Ichthyol. Herpetol., Spec. Publ. 3.

Rathbun, R. 1894. Summary of the fishery investigations conducted in the North Pacific Ocean and Bering Sea from July 1, 1888 to July 1, 1892, by the U.S. Fish Commission Steamer *Albatross*. Bull. U.S. Fish Comm. Vol. XII for 1892, Wash., p. 127–201.

Roppel, P. 1982. Alaska's salmon hatcheries 1891–1959. Alaska Hist. Comm., Stud. Hist. 20, 299 p. Anchorage.

Strobridge, T. R., and D. L. Noble. 1999. Alaska and the U.S. Revenue Cutter Service, 1867–1915. Naval Inst. Press, Annapolis, Md., p. 18–23.

Tanner, Z. L. 1885. Report on the construction and outfit of the United States Fish Commission Steamer *Albatross*. U.S. Comm. Fish Fish., Rep. Comm. 1883:3–116.

__________. 1890. Exploration of fishing grounds of Alaska, Washington Territory, and Oregon during 1888 by the U.S. Fish Commission Steamer *Albatross*, Lieut. Commander Z. L. Tanner, U. S. Navy, commanding. Bull. U.S. Fish Comm. Vol. VIII for 1888, Wash., 95 p.

_________. 1891 The fishing grounds of Bristol Bay, a preliminary report upon the investigation of the United States Fish Commission Steamer *Albatross* during summer of 1890. Bull. U.S. Fish Comm. Vol. IX for 1889, Wash., p. 279–288.

__________. 1897. Deep-sea exploration: a general description of the Steamer *Albatross*, her applications and methods. Bull. U.S. Fish Comm. for 1896, p. 257–428.

Tingle, G. R. 1897. Report on the salmon fisheries for Alaska, 1896. Gov. Print. Off., Wash., 27 p.

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

UNITED STATES
DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
SCIENTIFIC PUBLICATIONS OFFICE
BIN C15700
SEATTLE, WA 98115

OFFICIAL BUSINESS

Penalty for Private Use: $300

PRSRT STD
POSTAGE & FEES PAID
U.S. DEPARTMENT OF COMMERCE
PERMIT NO. G-19

PROQUEST INFO. AND LEARNING M
300 N. ZEEB RD/P.O. BOX 1346
ATT: SER. ACQUISITIONS DEPT
ANN ARBOR, MI 48106-1346